



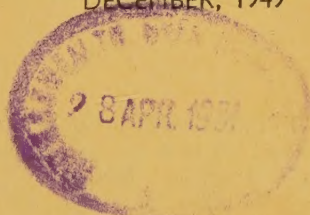
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NOTICES

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STUDIES OF PHORMIUM MANAGEMENT, MOUTOA ESTATE, FOXTON

By A. L. POOLE and W. R. BOYCE

HISTORY LEADING TO THE GOVERNMENT PURCHASE OF MOUTOA

THE Phormium industry in New Zealand, from its origin in the early years of the nineteenth century until 1930, was built largely on an export trade to cordage fibre markets overseas. This trade between 1900 and 1920 maintained an average export of approximately 20,000 tons of line fibre per year which represented an annual harvest of about 200,000 tons of green leaf. It was marked, however, by excessive fluctuations from year to year with a rapid decline from 1925 until exports ceased after 1933. These movements are shown graphically in Fig. 1. A small internal market for a few thousand tons of fibre existed, but its importance was overshadowed by the recurrent opportunities of the export market until the latter collapsed finally in 1933. It was only

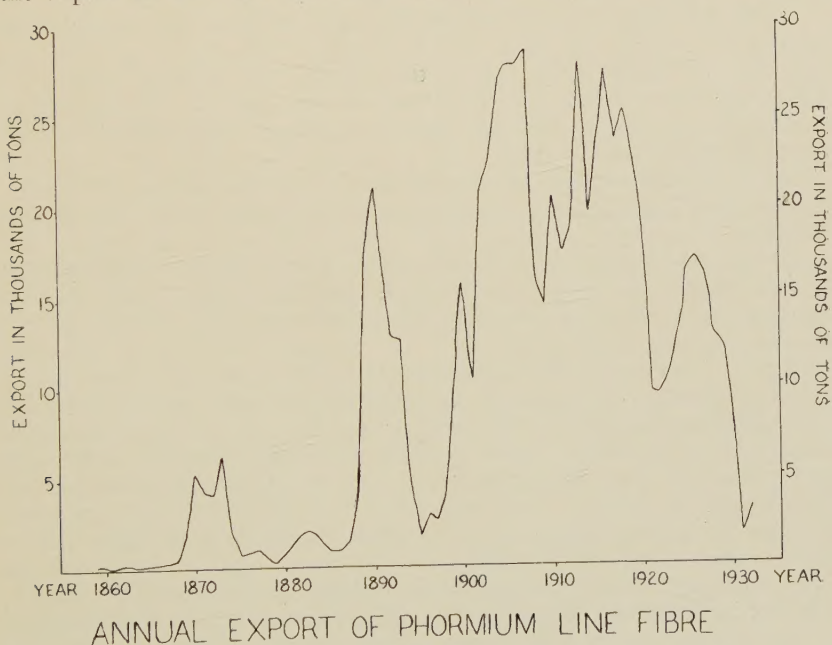


Fig. 1

then that the future of the industry was seen to lie in the potentialities of New Zealand's own fibre requirements. With the present world fibre shortage these requirements have been estimated at a minimum of 10,000 tons of unscutched fibre per year. Because of the shortage of green leaf the local industry cannot provide more than 35,000 to 45,000 tons per year which is equivalent to 4,000 to 5,000 tons of unscutched fibre.

What then has been the relation of the industry to its supplies of raw material? In the era of the export trade the use and development of supplies of leaf has been considered by A. H. Cockayne (Department of Agriculture Reports) and others to fall into three periods: the first up to 1900, when leaf was obtained from naturally occurring stands which were widely distributed over the North and South Islands; the second from 1900 to 1920, which marked the rise of indigenous induced areas (this term is explained in Section 2), of which those bordering the Manawatu River were the most extensive; and a third period after 1920 marked by a rapid decline of indigenous induced areas and an attempt to replace them by plantations.

The closing of the export era further hastened the decline of the indigenous induced areas, and rendered abortive, with few exceptions, efforts to establish plantations. It also frustrated a promising movement marked by the work of J. S. Yeates (D.S.I.R. Reports) and to a lesser extent that of Seifert, Walls and Wood to improve by selection and breeding the qualities of the plant.

Reasons for the fluctuating fortunes and failure of *Phormium* on the world cordage fibre market were:—

1. It was available only in comparatively small quantities—a maximum of 28,000 tons in a world hard fibre demand approaching 400,000 tons.

2. As a cordage fibre its quality was more variable and tended to be inferior to manila and sisal. These defects were due in part to (a) variations of plants occurring in the natural and induced areas, (b) difficulties in separating the fibre from the leaf, and (c) the number of small mills operating and a large element of opportunism which attended the working of some of them.

3. After 1930 the increased quantities of sisal from East Africa and the economic depression in the ensuing years dealt a death blow to the industry.

Strenuous efforts were made at various times to retrieve the position by improving machinery, instituting a grading system, and later by research work on plant breeding and fibre processing. However, this did not avert the final collapse.

There remained local requirements to support an industry. These included fibre for cordage, lashings, baling and binder twine, plasterer's tow, upholsterer's tow, matting and woolpacks, the last being the most substantial requirement. New Zealand uses some 800,000 packs each year to bale its wool clip, for which a total of 4,000 tons of unscutched fibre would be needed. Although classed as a hard fibre, *Phormium* occupies an intermediate position in fibre quality between typical hard fibres such as sisal and manila and soft fibres such as jute, and can cover a range of uses in both groups in cordage and textile work. Hence, whereas in overseas cordage markets *Phormium* was at a disadvantage, it has because of its wide range of uses marked advantages for the local market.

In 1933 an attempt was made to establish in Foxton, New Zealand, an industry for manufacturing woolpacks from the tow scutched out in producing line fibre for export. Previously this tow had been a by-product for which little economic use existed. However, such was the state of decline of the industry in this and following years that insufficient tow was produced to maintain production, and many difficulties were encountered when line fibre had to be treated on machinery not designed for the purpose. This period also marked the passing of most of the remaining indigenous induced areas from *Phormium* production to other agricultural purposes, and brought to an end many attempts to establish plantations. The year 1935 marked a crucial point in the development of the industry. A decision was made by the executives of the private company which had commenced manufacturing woolpacks that only with government assistance to ensure their supplies of leaf and to enable the factory to be re-equipped with machinery suitable for handling line fibre could they continue production. This assistance was given. In 1938 the government took over, for development and research, the Moutoa estate, the last large area of *Phormium* remaining in the Manawatu.

The industry has thus been stabilized temporarily but its future which depends on adequate supplies of green leaf is not yet assured. Such supplies must come from both naturally occurring and indigenous induced areas. The problems of managing and maintaining these in economic production tend to become increasingly difficult. Some will be replaced by managed plantations with their improved working conditions, higher yield of fibre per acre and more even quality of leaf, while other areas will have to be maintained in production. In the latter task research will be necessary to enable the requirements of the industry to be adjusted to the ecological requirements of the plant.

ECOLOGY OF INDUCED PHORMIUM COMMUNITIES

To date, by far the greater part of green leaf for the fibre trade has come from what Cockayne (1928) termed "indigenous induced" swamps. This term was applied by that author to areas in which the vegetation was dominated by indigenous plant species, but in which the structure of the vegetation was altered considerably by interference. One cannot do better than quote Cockayne's description of such indigenous induced *Phormium* communities, "In various parts of New Zealand proper, especially where large rivers overflow their banks, there are extensive areas of ground, perhaps extremely wet in winter, but quite dry in summer, occupied by bushes (tussocks) growing closely of *Phormium tenax*, making apparently a pure association. To one unversed in this class of vegetation, it would unhesitatingly be considered primitive, yet it has arisen solely through draining the *Typhaphormium* swamp described in Part II. Nor would it remain stable for long were it not that various invading species are removed by the owners of the 'flax-swamps,' so called:

"As has been explained, the primitive swamp is wet at all seasons and contains abundance of *Typha angustifolia* (in a wide sense), but, as with *Phormium*, it only occurs more or less stunted here and there in the shallowest water or fringing the margin of the swamp. Into the latter deep drains are cut, its water-content is greatly lessened, and in a year or two the *Phormium* present attains its full dimensions; then

the substratum becoming drier the *Typha* will languish and young *Phormium* plants come up thickly all over the drained ground. In a few years such attain their full dimensions and the former swamp will be almost pure *Phormium* 3.6 m. high, under favourable conditions."

It will be seen from Cockayne's description that the underlying cause bringing about the vegetation changes was the effect of altered water table conditions on the zonation of communities in a swamp.

The Moutoa *Phormium* area at the time of purchase in 1938 was typical—apart from a somewhat excessive encroachment of introduced weed species—of such an indigenous induced swamp. It was indeed the last of any size remaining of the once-extensive area along the Manawatu River banks from about Palmerston North to Foxton.

Various causes led to the failure of these Manawatu swamps for the production of *Phormium*: overdrainage, stopbanking, insect damage and weed invasion, the disease known as "yellow leaf," the cause of which is as yet not diagnosed, and the greater value of the land for other agricultural purposes. But from the information available the main cause underlying the disappearance of these *Phormium* areas appears to have been either the failure to recognize or the inability to provide, the ecological requirements for induced *Phormium* under periodic cutting. The narrow belt which *Phormium* occupied in the primitive community indicates that its requirements are exacting and vary within small limits. (To what extent these factors are determined by special physiological requirements of the plant or by the interaction of factors outside the plant is a subject for future research.) This belt lies between swamp forest and scrub on the dryer side, and *Typha angustifolia* and sedges on the wetter side.

The development and decline of these areas can be traced briefly as follows: Initial drainage led to the spread of *Phormium* from its original narrow belt to occupy the *Typha* and sedge zones. This spread of *Phormium* and its increased growth was followed by cutting operations. Further exploitation of the areas required more extensive drainage and stopbanking to give flood protection. Then followed a characteristic decline marked by insect damage, weed invasion and yellow leaf disease. Secondary causes such as fires, stocking and poor cutting practices aggravated the rate of decline in particular cases. Miller (1917) has described the sequence of events for the Makerua area (one of the Manawatu swamps) in relation to insect damage; it was drained in the 1890's and milling commenced in 1900. More intensive development followed and the first incidence of grub attack was reported in 1902. Later reports show that diseases of the yellow leaf type were first reported about 1908, while serious losses from this disease were reported by L. Cockayne (1920). Miller refers also to the contrast provided by the Moutoa area which at the time of his investigations remained free from the troubles affecting other areas.

That the soil moisture conditions can readily be upset by drainage is apparent; that the prevention of silt laden floods from covering the areas removes one of the conditions for optimum growth is also evident. Because of free flooding and restricted drainage, the Moutoa alone of all the once extensive Manawatu areas remained in *Phormium*. Under similar conditions *Phormium* stands along the lower reaches of the Ruamahanga River flowing into Lake Wairarapa have also yielded heavy crops of healthy leaf for a long period of time.

THE MOUTOA AREA

HISTORY AND GENERAL DESCRIPTION

The Moutoa Phormium Development Area purchased by the Government in 1940 covers some 5,000 acres on the north bank of the Manawatu River, about five miles from its mouth. It is part of a very shallow semi-basin with contours ranging from about 6 ft. to 20 ft.* above mean sea-level, with about two-thirds of the area lying between the 6 ft. and 9 ft. contours. The highest contours are along the river where continual flooding and deposition of sand has formed a low levee, while the lowest contours are to the north of the area, roughly parallel with the general flow of the river. Prior to purchase, flooding occurred on an average of four times per year. The size and distribution of these floods is shown in Fig. 2.

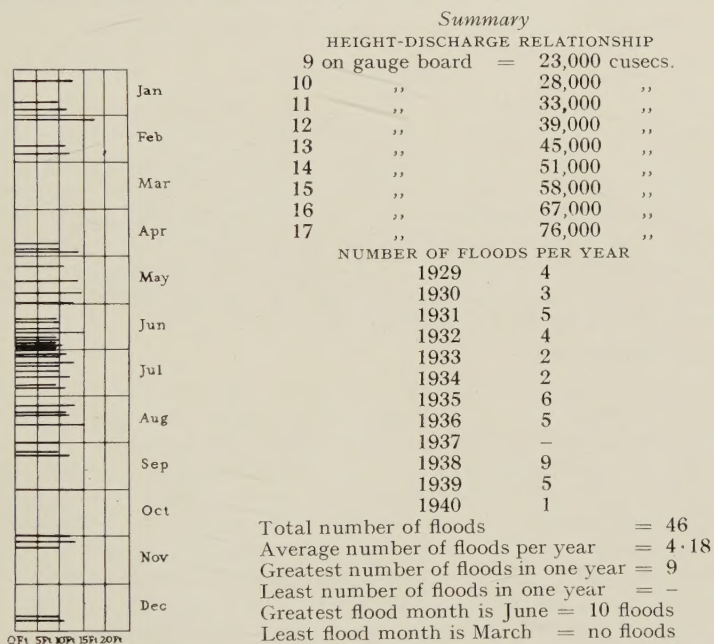


FIG. 2.—FLOODING OF MANAWATU RIVER

COMPOSITE GRAPH OF FLOODING FOR ELEVEN YEARS ENDING 31 MARCH, 1940

Height of River on Gauge Board at Fitzherbert bridge, Palmerston North. Floods occur at nine feet or over.

Recent sediments deposited by the Manawatu River, together with peaty phases in the lower-lying parts, form the soils. The sedimentary deposits range from sands and sandy silts on the river banks to silts and clay loams on the lower ground away from the banks. All these recent sedimentary deposits are underlain at depths of from 18 in. to 12 ft. by a more consolidated bluish clay loam in which are the stumps of an old forest. Where peaty phases or even shallow silt phases have

* River Levels: All levels are to datum of Manawatu-Oroua River Board. Zero is Low Water Spring Tide at Manawatu Head. To this datum mean sea level is reduced level 4. Therefore if 4 ft. is subtracted from all levels it will give the amount of such levels above mean sea level.

shrunk through drainage, these stumps appear above the surface. All soil types are fertile as far as plant food requirements are concerned and are less acid than is usual for meadow soils.

What now roughly constitutes the area was purchased in 1870 in London, for the purpose of clearing and developing farmlands. Draining commenced within a short time and the dry river banks were soon cleared of forests and were farmed. As draining proceeded into the interior of the area, burning was commenced but never succeeded in killing the swamp vegetation. About this time the *Phormium* fibre industry had become well established and in the year 1887 the cutting of green leaf commenced on the area. Nevertheless, further attempts were made to clear by burning up to about 1900. Commencing with a change of ownership in 1902, the area was thereafter managed for *Phormium* leaf production. Drains were maintained, weeds were dealt with in the best *Phormium* stands, and a certain amount of planting of *Phormium* and thickening up of natural stands was done.

VEGETATION SURVEY

Just prior to purchase in 1940 a 100 per cent vegetation survey, combined with an estimate of the total *Phormium* green leaf crop, was made (Poole, 1946). There follows a detailed description of this survey, since from it can be reconstructed the approximate boundaries of the original plant communities and the alterations following drainage. Upon this information depended the formulation of any plans for the future management of the area. A knowledge of the position *Phormium* occupied in the vegetation zonation and of the conditions under which optimum stands could be stabilized was basic.

METHODS OF SURVEY

The base line of the survey was a cut inspection line running east and west through the whole length of the area. At right angles from this, and at ten-chain intervals, offset lines were cut to the river and to the northern boundary; thus the area was covered by parallel cut lines at ten-chain intervals. Along these lines two chainmen and two mappers cruised. Each mapper recorded in field note books all the vegetation by communities on one side of the line, and where *Phormium* was present assessed the stand in tons of green leaf per acre as at maturity. The information thus obtained was transferred to a base map of five chains to an inch. From this, all basic data such as the total *Phormium* stand, the area and distribution of the plant communities, etc., was obtained. Fig. 3 is a reproduction of the vegetation map showing plant communities and the *Phormium* stands.

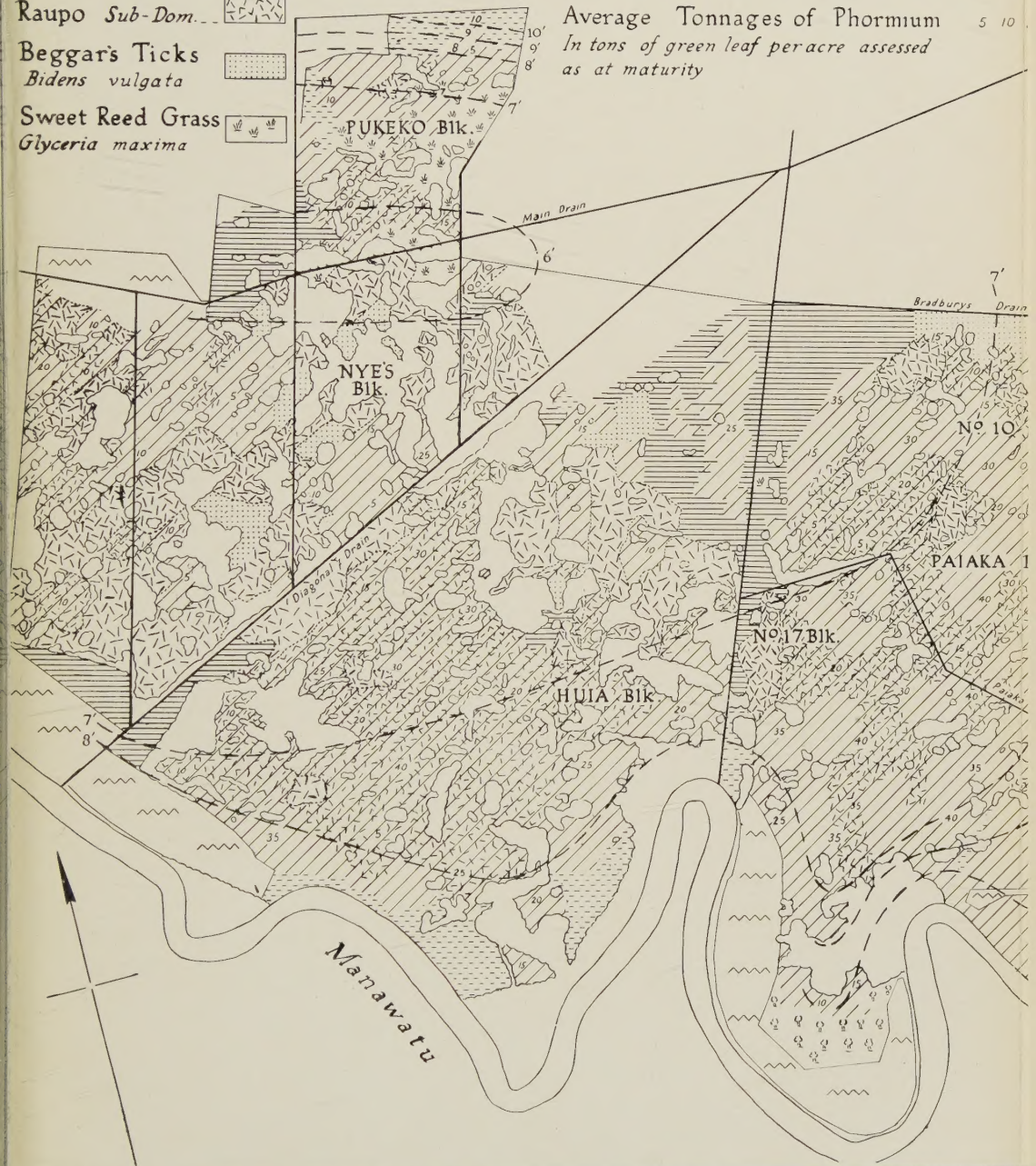
The determination of the important plant communities was obtained by studying aerial photographs combined with field inspections. The communities selected were named after the dominant plants, as follows:

Phormium		(<i>Phormium tenax</i>)
Raupo		(<i>Typha angustifolia</i>)
Tall fescue		(<i>Festuca arundinacea</i>)
Beggar's ticks		(<i>Bidens vulgata</i>)
Reed sweet grass		(<i>Glyceria maxima</i>)
Crack willow		(<i>Salix fragilis</i>)
Remnant kahikatea forest		
Miscellaneous weeds and sown pasture.		(<i>Podocarpus dacrydioides</i>)

Legend of Plant Associations

Phormium	Commercial Crop above 5 Tons per acre		Miscellaneous Weeds
Willow	<i>Salix fragilis</i>		Pasture and Ploughed Land
Fescue	<i>Festuca arundinacea</i>		Indigenous Forest Remnant
Raupo	<i>Typha angustifolia</i> Dominant		Blackberry <i>Rubus spp</i> Sub Dominant
Raupo Sub-Dom.			
Beggar's Ticks	<i>Bidens vulgata</i>		
Sweet Reed Grass	<i>Glyceria maxima</i>		

Average Tonnages of Phormium 5 10
In tons of green leaf per acre assessed as at maturity



Each of these communities will be described, and at the same time notes which can be followed on Fig. 3, made concerning their distribution. This map was drawn with particular reference to the commercial crop of *Phormium*. Stands of about 20 tons of green leaf per acre were dominated by *Phormium* and were considered as *Phormium* communities. When the stand dropped below 20 tons per acre associated plants were becoming dominant and *Phormium* sub-dominant. This must be borne in mind when reading the map. The lowest commercial stand of *Phormium* was one that yielded about five tons per acre of green leaf.

Relevant statistics of leaf tonnages and areas covered by different communities are given in Tables I and II.

The Phormium Community

Phormium is a perennial plant with short, much branched rhizomes. The ends of the branches are semi-erect, terminating in a fan bearing six to ten leaves. New leaves appear on alternate sides in the centre of the fan, live for eighteen months, and then die off from the outside of the fan as they are displaced by succeeding younger leaves.

A fan, about its fourth or fifth year, reaches a stage of equilibrium at which the number of new leaves produced is balanced by the number dying off. The fan then bears from six to ten harvestable leaves and is considered mature for cutting. A complete cut is made in which all leaves of a fan and all fans of a plant are cut six to nine inches above ground level. The life of a fan and its leaf production is terminated by flowering which may take place any time after its third year of growth. It is then replaced by shoots from the base of the fan which develop into young fans branching from the old rhizome. In this way a *Phormium* bush spreads outwards from its initial position with young fans on the periphery. In time, older fans in the centre flower and die out, leaving a ring of younger fans, which in turn may break up into isolated clumps with nothing but the old rhizome traces to show a connection with the origin of the bush. It is this method of growth which gives the random distribution of small clumps of fans, typical of the best induced stands. As little regeneration from seed appears to take place in dominant *Phormium* stands, it is possible that plants growing to-day had their origin in the first induced stands, and have since continued by vegetative growth. Another characteristic of the growth habit is that young rhizomes arise at progressively higher levels, as a result of which the bush tends to rise above the surrounding soil surface. Where flooding and silting takes place old leaves and decaying vegetation are incorporated with silt in a loose friable mulch round the base of the plant. By this means the soil level keeps apace with the production of new plants, and optimum conditions for growth are provided. On the other hand, in the absence of flooding and silting, and where drainage tends to compact the surface soil, younger fans may be well above the soil level. Roots then become exposed and subjected to damage by desiccation and insect attack. Insect populations may build up quickly in the absence of flooding and greatly increased damage to aerial and subterranean portions of the plant results.

In the optimum facies of the *Phormium* community *Phormium* grew gregariously, producing a maximum weight of about forty tons of green leaf per acre (see Fig. 5). In these gregarious stands, other plants

TABLE I. MOUTOA ESTATE VEGETATION SURVEY
 AREA IN ACRES OF VARIOUS TYPES OF VEGETATION. AREA IN ACRES SHOWN THIS :— DOMINANT 23, SUBDOMINANT (23)
 Compiled by P.W.D. from basic Vegetation Survey Map

	Terrell's.	Springs.	Oldfield's	Kari.	Toss'.	No. 18.	No. 10.	Paiaka.	No. 17.	Huia.	Nye's.	Pukeko.	Total.	Per cent of Total
Phormium	149	66 247	256	147	88	49	209	299	137	437	155	74	2313	49.4
Willow	—	36	70	84	17	57	55	75	66	251	150	30	891	19.0
Fescue	43	59(145)	38(24)	50(76)	64(88)	17(40)	11(43)	1(47)	9(31)	38(34)	(20)	22(32)	352(580)	7.5(12.2)
Raupo	6(9)	4(121)	44(59)	18(55)	—	2	17(81)	3(69)	12(53)	103(84)	169(40)	2(30)	380(801)	8.1(17.1)
Beggar's ticks	—	—(30)	—	—(3)	—	—	20(30)	—(22)	—(33)	9(126)	25(149)	—	54(390)	1.2(8.3)
Reed sweet grass	—	—	—	—	2	—	2	—	—	12	22(5)	27(9)	65(14)	1.4(0.3)
Miscellaneous	—	—	—	—	—	—	62(3)	—	6	78(34)	64(25)	24	234(62)	5.0(1.3)
Forest	—	12	—	—	—	—	—	10	17	—	—	—	39	0.8
Pasture, etc.	18	45	26	—	—	37	—	51	86	41	20	32	356	7.6
Blackberry	—(140)	—(48)	—(125)	—	—	—	—	—	—	—	—	—	—(313)	—(6.7)
Total	216	469	434	299	171	162	376	439	333	969	605	211	4684	100.0

NOTES: Phormium areas include only those yielding 5 Tons per acre or over.
 Willow areas exclude clumps smaller than 1 square chain.

TABLE II. PHORMIUM CROP
SCHEDULE OF ACRES CARRYING VARIOUS WEIGHTS PER ACRE — AND GROSS TONNAGES
Compiled by P.W.D. from basic vegetation survey map

Tons per acre.	Torrell's.	Springs.	Oldfield's	Kari.	Toss.	No. 18.	No. 10.	Palaka.	No. 17.	Hua.	Nye's.	Pukeko.	Totals.	Per cent of total area.	Tons.
No flax or less than 5 tons															
5 - 10	67	156	178	152	83	113	167	140	196	532	450	137	2371	50.6	
10 - 20	41	59	18	45	27	—	50	—	—	59	81	31	411	8.8	3,100
20 - 30	79	126	20	72	61	—	61	20	16	120	64	42	681	14.6	9,900
30 - 40	29	46	70	10	—	12	66	39	28	192	10	1	503	10.7	12,500
40	—	16	98	20	—	37	32	220	86	63	—	—	572	12.2	19,700
	—	66	50	—	—	—	—	20	7	3	—	—	80 (66)	1.7 1.4	3,200
Totals in acres	216	469	434	299	171	162	376	439	333	969	605	211	4684	100	
Gross weight of Flax in tons/acre on Gross Area	2,200	4,000	7,600	2,300	800	1,500	4,000	9,800	4,200	9,300	1,800	900			48,000
Tons/acre on Flax Area	11.1	9.9	17.5	7.7	4.7	9.3	10.6	22.3	12.6	9.6	3.0	4.3			10.4
	14.7	16.2	30.0	15.6	9.1	30.6	19.1	32.7	30.5	21.1	11.6	12.2			21.5

40 Tons/acre gives 6.5 per cent of crop for 1.7 per cent of area
 30 " or over/acre " 47.0 " " 13.9 " " "
 20 " " " 73.0 " " 24.6 " " "
 10 " " " 93.5 " " 39.2 " " "
 5 " " " 100.0 " " 48.0 " " "

were not present in any quantity. Quadrat counts showed that the number of fans per acre was fairly constant varying from 20-25,000. A typical quadrat is shown in Fig. 4, and the position of plants recharted seven years later shows the movement which has taken place. The leaves in such a stand reached a height of eight to ten feet and through touching and interlacing excluded sunlight from the floor, thus making it unsuitable for colonization by other plants. A few managed to exist and scattered *Blechnum procerum*, *Carex ternaria*, *C. secta*, *Agrostis tenuis* and *Typha angustifolia* were most commonly present. Occasional shrubs, as high as or somewhat higher than *Phormium*, were also present. The species were *Coprosma propinqua*, *C. robusta* and hybrids between these two, *C. areolata*, *Muchlenbeckia australis* and *M. complexa*, often scrambling over other shrubs, and *Pittosporum tenuifolium*. The shrubs must have been much more plentiful at one time, but many were probably cleared with each cutting of the *Phormium* leaf. Rising about three times the height of the *Phormium* were scattered cabbage trees (*Cordyline australis*).



FIG. 4.—Basal areas of *Phormium* bushes in an optimum *Phormium* stand.

Over the whole Moutoa Estate, *Phormium* stands of above twenty tons per acre covered 1,140 ac., or approximately one-quarter of the total; while stands below this amount covered 1,040 ac. Gregarious stands occurred in areas up to 150 ac. in extent. They were situated away from the river banks, mainly between the seven to twelve-foot contours (Oldfield and Paiaka Blks.), and had a decided relationship to the drainage and the history of the drainage.

Under conditions both drier and wetter than those which favoured the optimum facies, *Phormium* became more widely spaced and other plants more plentiful. On the dry side, *Phormium* bushes became scattered, though individually larger. Old isolated plants had an outwardly spreading ring of fans. Shrubs, mainly *Coprosma* spp., *Muchlenbeckia australis*, and *Cordyline australis* increased greatly in the open *Phormium* stand. This type of community was common as the optimum *Phormium* stands approached the river bank.



FIG. 5.—A good stand of *Phormium*, Oldfield's Blk.

A common sub-dominant plant on the dry side was blackberry, *Rubus laciniatus* and *R. ulmifolius*, and it sometimes also entered optimum stands. The main area in which it occurred was towards the eastern part of the estate within approximately the 10-13 ft. contours.

The most common sub-dominant to *Phormium*, which gradually passed into a dominant as conditions became drier, was tall fescue (*Festuca arundinacea*). This facies occurred near drains mainly in the eastern half of the estate or in proximity to the river bank. In the latter area it was invariably accompanied by goat's rue (*Galega officinalis*), and bindweed (*Calystegia sepium*). Tall fescue is a prolific seeder in these districts, and where conditions suit it, has the ability to invade the base of *Phormium* bushes or the tops of *Carex secta* clumps. By itself, it forms dense tussocks which in the second season will grow as much as 2 ft. above the ground level. Inundation of about one week is sufficient to kill tall fescue.

Carex ternaria which was present throughout all *Phormium* stands sometimes increased over small areas to form the dominant plant.

On the wet side of the optimum *Phormium* facies raupo (*Typha angustifolia*) was the most common sub-dominant. As conditions became wetter the more scattered and stunted in growth became the *Phormium*, finally giving way to raupo entirely. The delicate balance between these two plants was the best indication of optimum conditions for *Phormium*. In places beggar's ticks (*Bidens vulgata*) came in with raupo.

Raupo Community

In the optimum facies of this community raupo occurred gregariously with a dense layer of rhizomes about 6 in. under the surface, giving other plants no opportunity to invade. It had a marked seasonal varia-

tion as the leaves were killed by the first heavy frosts and young shoots did not appear again until October. It occurred most commonly in the low-lying western parts where it occupied extensive areas. In the central portion (Paiaka and the surrounding blocks), it was in delicate balance with *Phormium* (see Fig. 6). Within a short distance of twenty yards or so, there could be a transition from dominant *Phormium* to dominant raupo and back again (see Fig. 7). In other words, a large part of the area consisted of a mosaic of these two communities and transitional stages between them.



FIG. 6.—*Phormium*—raupo balance, Diagonal Blk.



FIG. 7.—A stand of sweet reed-grass; *Phormium* and willow in the background.

The transitional facies from *Phormium* to raupo have been described under the *Phormium* community. As conditions became wetter than suited raupo, this plant gave way to reed sweet grass (*Glyceria maxima*), beggar's ticks and *Carex secta*. The junction between the first plant and raupo was abrupt because of the habit of reed sweet grass of creeping over the ground to the exclusion of all else. Beggar's ticks, being an annual, was an ephemeral plant. Its germination and persistence seemed to depend upon surface water conditions.

Reed Sweet Grass Community

This naturalized species frequently accompanied by another naturalized plant, the reed canary grass (*Phalaris arundinaceae*), formed limited communities which covered the ground to the exclusion of all other vegetation. As noted before, the boundary between this and the surrounding communities was sharp. The community occupied the lowest lying, wettest parts of the area, a favourite locality being along the banks of the lowest drains from whence it grew into the drains themselves. Drains must have been one of the main means of spreading the plant.

Beggar's Ticks Community

This community, of a naturalized annual plant, occupied fairly extensive areas in the low lying western parts. Its ecological status was difficult to determine, though later knowledge placed it as an ephemeral community. It seemed to be present mainly on areas where *Phormium* had been killed out, through flood waters lying on cut plants or for other reasons, and before other perennial plants had time to migrate to the area. (See Fig. 8.)



FIG. 8.—A deteriorated *Phormium* stand; raupo and beggar's ticks invading.

In the optimum facies of this community, beggar's ticks grew gregariously to the exclusion of most other species. Plants grew very closely to a height of 4-5 ft. and in the autumn produced an abundant crop of seed which germinated as the surface water receded in the spring. Beggar's ticks also appeared commonly on freshly broken or cultivated land.

Miscellaneous Weeds Community

This community, consisting mainly of low growing weed plants such as *Polygonum hydropiper*, *P. persicaria*, *Rumex* spp., *Juncus* spp., *Bidens vulgata*, *Ranunculus* spp. etc., also appeared to be an ephemeral community, which would give way to other plants in time. It occurred only in limited areas in the northern portion of the estate.

Tall Fescue Community

This naturalized species appeared as conditions became drier than those favoured by optimum *Phormium* stands. At first it occurred about the base of *Phormium* plants and as an invader on the tops of *Carex secta*. As drier conditions developed it tended to become the dominant plant growing as tufts which raised themselves from the ground. The most frequent occurrence of the community was within the high contours along the river bank or along the freer flowing drains. In the former position it was invariably accompanied by much goat's rue, and in the latter by such plants as creeping buttercup. Over extensive areas in the higher contours tall fescue was a sub-dominant to *Phormium*, and in plantations which had been established along the bank it had invaded to a serious extent.

Crack Willow Community

This naturalized species propagates itself readily from twigs, branches or stumps. An area such as Moutoa which is subject to inundation by floods carrying willow twigs and logs is an admirable propagating place. This was shown in the survey which determined that 20 per cent of the area was covered by willows varying from single trees to groves up to 20 ac. in extent. The trees grew to a height of about 35 ft., and eventually killed by shading all plants other than ground floor herbs. The groves became a tangled mass of stems as they were broken off by wind and flood damage and took root.

The distribution of the community was indiscriminate and depended mainly upon chance dispersal of propagating material. A certain amount was also propagated by using willow wood for tram sleepers and fencing posts.

Remnant Kahikatea Semi-Swamp Forest Community

Remnants of the forest, much damaged by animal grazing, occurred along the drier river bank. In the best preserved of these, the dominant trees were kahikatea and pukatea (*Laurelia novae-zelandiae*). Other plants making up this community are recorded in the appended list of species.

Sown Pastures

Along the river banks where the semi-swamp forest once grew almost continuously, but was early cleared for cultivation, pastures composed mainly of rye-grass and white clover were sown. Tall fescue and goat's rue invaded these to a considerable extent.

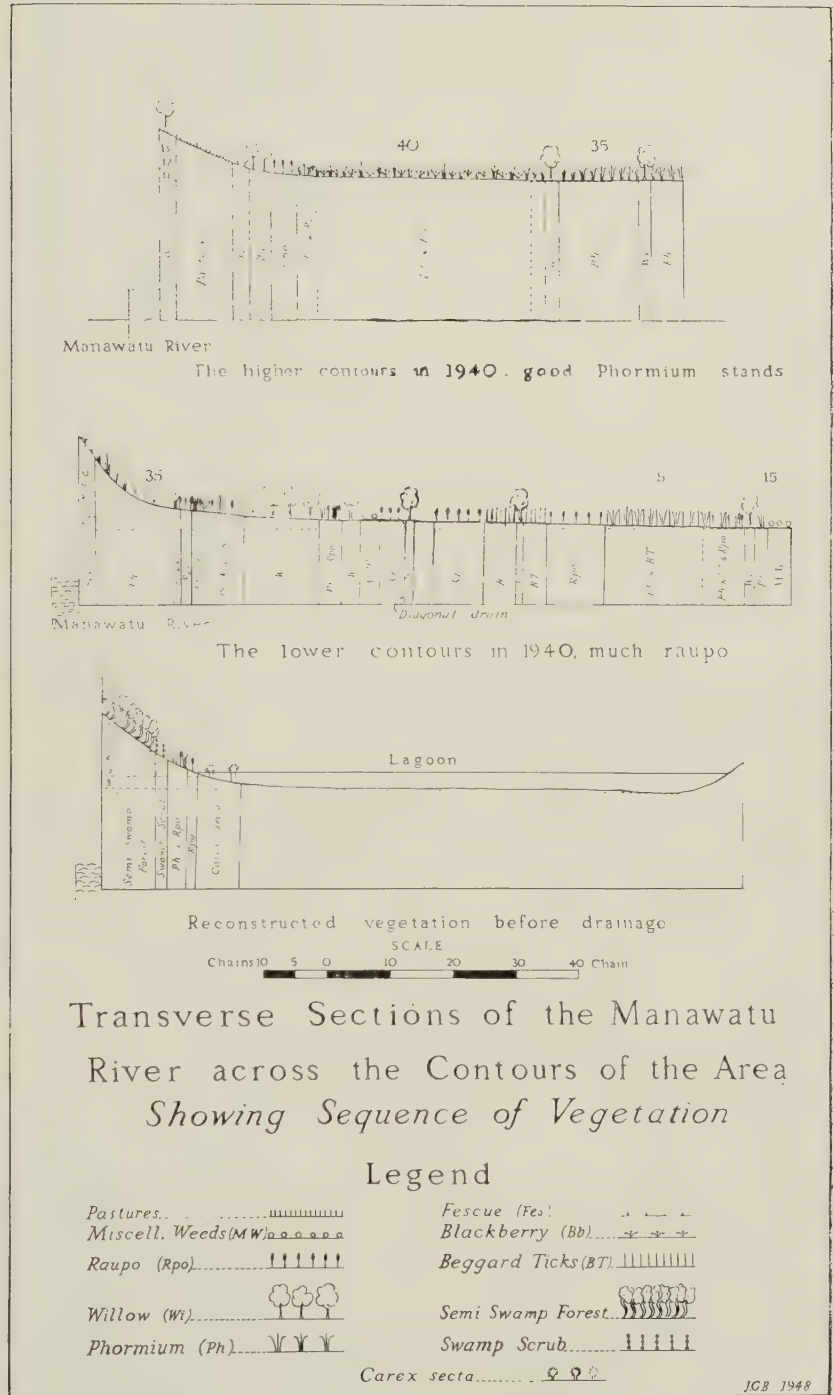


Fig 9

DISCUSSION ON THE DISTRIBUTION OF THE PLANT COMMUNITIES

From the vegetation map showing the distribution of the various communities, from remnant species and communities, and from old survey maps and verbal history, it has been possible to reconstruct the original vegetation and to trace the changes introduced by drainage and management. (See Fig. 9.)

In the virgin condition the vegetation consisted of a zonation of communities closely correlated with the spatial change in the height of the water table. The comparatively dry river bank supported a semi-swamp *Podocarpus* forest—a survey carried out in 1866 by J. Thompson, shows forest around the river bank of most of the Moutoa Estate—inside which would come a belt of swamp scrub consisting of *Coprosma* spp., *Cordyline australis*, etc. In this belt scattered *Phormium* would be present. It gradually increased to form a relatively pure but narrow belt inside the scrub. This in turn would give way to *Typha* forming fairly extensive communities. Inside this again would be open shallow water with scattered *Carex secta*.

The series of changes commenced by European occupation was initiated by the clearing of the forest and the cropping or sowing of pastures of European pasture species along the river banks. Drainage of the swamp proper then altered the water-table conditions, bringing about a change in dominant species of the different zones. Conditions in the *Typha* belt became such that *Phormium* invaded it, or that *Phormium* seedlings already present but undeveloped grew and became dominant. As drainage proceeded this also occurred to some extent in the shallow water areas where *Carex* was present. Burning and attempted clearing of parts did not alter the vegetation materially, because floods and wet winter conditions restored the dominants.

Then came the development of the *Phormium* industry, and the management of the area for *Phormium* leaf. The induced *Phormium* stands were fostered and weed species were cleared to some extent as the stands were cut over. On the poor margins of these stands, *Phormium* was "thickened" by planting and some planting was also done on the cleared dry river bank. In the course of time a number of adverse changes, i.e. adverse from the point of view of *Phormium* management, took place. The encroachment of a number of introduced weed species could not be halted. Tall fescue and goat's rue invaded areas too dry for optimum *Phormium* stands. In planted areas on the dry river bank, this invasion seriously affected the plant. Crack willow invaded any part where vegetative material happened to be spread by floods or human agency. Once crack willow became established there seemed no method of control other than removal of all parts of the tree. Ring-barking was only partially effective. In parts, scarcely too dry for optimum *Phormium*, blackberry became an invader, sometimes to such an extent that it hindered cutting operations. This again was a difficult weed to deal with, as it never seemed possible to eradicate it.

Drainage of the estate brought about some subsidence in the silt and sandy soils, and a considerable amount in the peaty soils. This reduced the effectiveness of the drains, particularly in the lower parts of the area. The main effect was the slow draining off of flood waters, which in turn brought about changes in vegetation, in particular the killing out of *Phormium* as a result of excessive wetness and flood waters lying on freshly cut plants. These areas were invaded temporarily, some-

times by the annual *Bidens vulgata* and finally by *Typha*, a reversal of the succession which took place after the original drainage. Where conditions were wettest—probably too wet at any stage for *Phormium*—sweet reed grass and reed canary grass invaded the area and formed pure communities.

From the above description it will be seen that *Phormium* was introduced over wide areas by a succession of drainage activities. It would invade first the raupo belt and follow this into the lagoon areas as raupo found its way there following drainage. By planting it was extended into the swamp scrub and even cleared forest areas. It therefore finally covered many areas sub-optimal to it, but remained in these only as long as management practice was intense enough to keep competing weeds in check.

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LIST OF SPECIES PRESENT ON THE MOUTOA AREA

This list is compiled of plants seen on the Moutoa area between the years 1940-1948. It is possible a number of rarely occurring species have been missed though all important plants have been noted. The main habitat of the species has been divided roughly into river bank and semi-swamp. This was a good natural classification in 1940. Since then, drainage and stopbanking operations essential for plantation development have made conditions much drier. Subsequent vegetation surveys show that this has altered the distribution of some plant communities, as a result of which the original classification into river bank and semi-swamp has been modified.

Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
Monimiaceae			
<i>Hedycarya arborea</i> Forst.	I	Forest	
<i>Laurelia novae-zelandiae</i> A. Cunn.	I	Forest	
Lauraceae			
<i>Beilschmedia tawa</i> Hook. f.	I	Forest	
Ranunculaceae			
<i>Ranunculus repens</i> L.	N		X
<i>Ranunculus sceleratus</i> L.	N		X
Piperaceae			
<i>Macropiper excelsum</i> (Forst. f.) Mig.	I	Forest	
Fumariaceae			
<i>Fumaria muralis</i> L.	N	X	
Cruciferae			
<i>Barbarea verna</i> (Mill.) Asch.	N		X
<i>Barbarea stricta</i> Fries	N		X
<i>Brassica campestris</i> L.	N	X	

Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
<i>Brassica oleracea</i> L.	N	X	
<i>Capsella bursa-pastoris</i> (L.) Medik.	N	X	
<i>Cardamine heterophylla</i> (Forst. f.) E. Schulz	I		X
<i>Coronopus didymus</i> (L.) Sm.	N	X	
<i>Coronopus procumbens</i> Gilib.	N	X	
<i>Lepidium rudemale</i> L.	N	X	
<i>Nasturtium officinale</i> R. Br.	N		X
<i>Nasturtium palustre</i> (Leyssar) DC.	I		X
<i>Raphanus sativus</i> L.	N	X	
<i>Sisymbrium officinale</i> (L.) Scop.	N	X	
Violaceae			
<i>Melicytus ramiflorus</i> Forst.	I	Forest	
Caryophyllaceae			
<i>Cerastium glomeratum</i> Thuill.	N	X	
<i>Sagina procumbens</i> L.	N	X	
<i>Silene gallica</i> L.	N	X	
<i>Spergula arvensis</i> L.	N	X	
<i>Stellaria graminea</i> L.	N		X
<i>Stellaria media</i> (L.) Vill.	N	X	
Portulacaceae			
<i>Portulaca oleracea</i> L.	N	X	
Polygonaceae			
<i>Muehlenbeckia australis</i> (Forst. f.) Meissn.	I	Forest	X
<i>Muehlenbeckia complexa</i> (A. Cunn.) Meissn.	I		X
<i>Polygonum aviculare</i> L.	N	X	
<i>Polygonum hydropiper</i> L.	N		X
<i>Polygonum persicaria</i> L.	N		X
<i>Rumex acetosella</i> L.	N	X	
<i>Rumex crispus</i> L.	N	X	X
<i>Rumex obtusifolius</i> L.	N	X	X
Chenopodiaceae			
<i>Chenopodium album</i> L.	N	X	
<i>Chenopodium pumilio</i> R. Br.	N	X	
Amarantaceae			
<i>Amaranthus deflexus</i> L.	N	X	
Linaceae			
<i>Linum marginale</i> A. Cunn.	N	X	
Geraniaceae			
<i>Erodium cicutarium</i> (L.) L'Her.	N	X	
<i>Erodium moschatum</i> (L.) L'Her.	N	X	
<i>Geranium dissectum</i> L.	N	X	
<i>Geranium molle</i> L.	N	X	
<i>Geranium robertianum</i> L.	N		X
Oxalidaceae			
<i>Oxalis corniculata</i> L.	I	X	
Lythraceae			
<i>Lythrum hyssopifolia</i> L.	N	X	
Onagraceae			
<i>Epilobium erectum</i> Petrie	I		X
<i>Epilobium pedunculare</i> A. Cunn.	I		X
<i>Fuchsia excorticata</i> L. f.	I	Forest	
Halorrhagaceae			
<i>Myriophyllum propinquum</i> A. Cunn.	I		Drains
Callitrichaceae			
<i>Callitriche verna</i> L.	I		Water
Pittosporaceae			
<i>Pittosporum tenuifolium</i> Banks et Sol.	I	X	X
Passifloraceae			
<i>Tetrapathea tetrandra</i> (Banks et Sol., ex D.C.)	I	Forest	

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Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
Myrtaceae			
<i>Metrosideros scandens</i> (Forst.) Druce	I	Forest	
<i>Metrosideros diffusa</i> (Forst. f.) W. R. B. Oliver	I	Forest	
<i>Metrosideros perforata</i> (Forst.) Rich.	I	Forest	
<i>Eugenia maire</i> A. Cunn.	I	Forest	
Hypericaceae			
<i>Hypericum perforatum</i> L.	N	X	
Tiliaceae			
<i>Elaeocarpus hookerianus</i> Raoul	I	Forest	
Malvaceae			
<i>Hoheria angustifolia</i> Raoul	I	Forest	
<i>Hoheria sexstylosa</i> Col.	I	Forest	
<i>Lavatera arborea</i> L.	N	X	
<i>Malva rotundifolia</i> L. em. Sm.	N	X	
<i>Plagianthus betulinus</i> A. Cunn.	I	Forest	
Euphorbiaceae			
<i>Euphorbia pepus</i> L.	N	X	
Escalloniaceae			
<i>Carpodetus serratus</i> Forst.	I	Forest	
Rosaceae			
<i>Potentilla anserina</i> L.	I		X
<i>Rosa eglanteria</i> L.	N	X	
<i>Rubus laciniatus</i> Willd.	N	X	X
<i>Rubus ulmifolius</i> Schott.	N		X
<i>Rubus australis</i> Forst. f.	I	Forest	X
Papilionaceae			
<i>Cytisus scoparius</i> Link.	N	X	
<i>Sophora microphylla</i> Ait.	I	Forest	
<i>Galega officinalis</i> L.	N	X	
<i>Lotus angustissimus</i> L.	N	X	
<i>Lotus uliginosus</i> Schkuhr.	N		X
<i>Medicago lupulina</i> L.	N	X	X
<i>Melilotus indicus</i> (L.) All.	N	X	
<i>Trifolium arvense</i> L.	N	X	
<i>Trifolium dubium</i> Sibth.	N	X	
<i>Trifolium hybridum</i> L.	N		X
<i>Trifolium pratense</i> L.	N	X	
<i>Trifolium repens</i> L.	N	X	
<i>Ulex europaeus</i> L.	N	X	
<i>Vicia angustifolia</i> L.	N		X
Salicaceae			
<i>Salix babylonica</i> L.	N	X	X
<i>Salix fragilis</i> L.	N	X	X
Moraceae			
<i>Paratrophis microphylla</i> (Raoul) Druce.	I	Forest	
Urticaceae			
<i>Parietaria debilis</i> Forst. f.	I	Forest	
<i>Urtica ferox</i> Forst. f.	I	Forest	
<i>Urtica linearifolia</i> Ckne.	I		X
Corynocarpaceae			
<i>Corynocarpus laevigata</i> Forst.	I	Forest	
Icacinaceae			
<i>Pennantia corymbosa</i> Forst.	I	Forest	
Sapindaceae			
<i>Alectryon excelsum</i> Gaertn.	I	Forest	
Cornaceae			
<i>Griselinia lucida</i> Forst. f.	I	Forest	
Araliaceae			
<i>Nothopanax arboreum</i> (Linn. f.) Seem.	I	Forest	
<i>Schefflera digitata</i> Forst.	I	Forest	

Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
Umbelliferae			
<i>Apium tenuifolium</i> (Moench) Thellung	N		X
<i>Conium maculatum</i> L.	N	X	
<i>Foeniculum vulgare</i> Mill.	N	X	
<i>Hydrocotyle novae-zelandiae</i> DC.	I		X
<i>Hydrocotyle moschata</i> Forst. f.	I		X
Myrsinaceae			
<i>Suttonia australis</i> A. Rich.	I	Forest	X
<i>Suttonia salicina</i> (Heward) Hook. f.	I	Forest	
Loganiaceae			
<i>Geniostoma ligustrifolium</i> A. Cunn.	I	Forest	
Oleaceae			
<i>Olea lanceolata</i> Hook. f.	I	Forest	
Apocynaceae			
<i>Parsonsia heterophylla</i> A. Cunn.	I	Forest	
Rubiaceae			
<i>Coprosma areolata</i>	I	Forest	X
<i>Coprosma propinqua</i> A. Cunn.	I	Forest	X
<i>Coprosma robusta</i> Raoul	I	Forest	X
<i>Coprosma tenuicaulis</i> Hook. f.	I		X
<i>Galium aparine</i> L.	N		X
<i>Galium palustre</i> L.	N		X
Caprifoliaceae			
<i>Lonicera japonica</i> Thunb.	N	Forest	
Valerianaceae			
<i>Kentranthus ruber</i> (L.) D.C.	N	X	
Compositae			
<i>Alchemilla arvensis</i> (L.) Scop.	N	X	
<i>Achillea millefolium</i> L.	N	X	
<i>Anthemis cotula</i> L.	N	X	
<i>Bellis perennis</i> L.	N	X	
<i>Bidens vulgata</i> Gren.	N		X
<i>Cotula australis</i> (Sieb.) Hook. f.	N	X	
<i>Cirsium arvense</i> (L.) Scop.	N	X	
<i>Cirsium lanceolatum</i> (L.) Hill	N	X	
<i>Crepis capillaris</i> (L.) Wallr.	N	X	
<i>Erigeron canadensis</i> L.	N	X	
<i>Erigeron crispus</i> L.	N	X	
<i>Erechtites prenanthoides</i> (A. Rich.) DC.	I	X	
<i>Gnaphalium luteo-album</i> L.	I	X	
<i>G. japonicum</i> Thunb.	N	X	
<i>G. purpureum</i> L.	N	X	
<i>Helminthia echinoides</i> Gaertn.	N	X	
<i>Hypochaeris radicata</i> L.	N	X	
<i>Leontodon hispidus</i> L.	N	X	
<i>Matricaria discoidea</i> D.C.	N	X	
<i>Olearia virgata</i> Hook. f.	I		X
<i>Senecio vulgaris</i> L.	N	X	
<i>Senecio jacobaea</i> L.	N	X	
<i>Sonchus asper</i> (L.) Hill.	N	X	
<i>Sonchus oleraceus</i> L.	N	X	
<i>Taraxacum officinale</i> Weber	N	X	
Primulaceae			
<i>Anagallis arvensis</i> L.	N	X	
Plantaginaceae			
<i>Plantago lanceolata</i> L.	N	X	
<i>Plantago major</i> L.	N		X
Polemoniaceae			
<i>Gilia squarrosa</i> Hook et Arn.	N	X	
Boraginaceae			
<i>Myosotis scorpioides</i> L. em. Hill	N		X

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Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
Solanaceae			
<i>Solanum dulcamara</i> L.	N		X
<i>Solanum nigrum</i> L.	N	X	X
<i>Nicandra physaloides</i> (L.) Gaertn.	N	X	
Convolvulaceae			
<i>Calystegia sepium</i> (L.) R.Br.	I		X
<i>Calystegia tuguriorum</i> (Forst. f.) R. Br.	I		X
<i>Convolvulus arvensis</i> L.	N	X	
Scrophulariaceae			
<i>Mimulus guttatus</i> D.C.	N		X
<i>Hebe salicifolia</i> Forst. f.	I		X
<i>Verbascum virgatum</i> Stokes	N	X	
<i>Verbascum thapsus</i> L.	N	X	
<i>Veronica arvensis</i> L.	N	X	
<i>Digitalis purpurea</i> L.	N	X	
<i>Veronica anagallis</i> L.	N		X
<i>Odontites viscosa</i> (L.) Rchb.	N	X	
Orobanchaceae			
<i>Orobanche minor</i> Sm.	N	X	
Verbenaceae			
<i>Teucrium parvifolium</i> Hook. f.	I	X	
Labiatae			
<i>Prunella vulgaris</i> L.	N	X	X
<i>Marrubium vulgare</i> L.	N	X	
<i>Mentha pulegium</i> L.	N	X	X
<i>Nepeta cataria</i> L.	N	X	
MONOCOTYLEDONS			
Alismataceae			
<i>Alisma plantago-aquatica</i> L.	N		Drains
Potamogetonaceae			
<i>Potamogeton ochreatus</i> Raoul	I		Drains
<i>Potamogeton cheesmanii</i> A. Bennett	I		Drains
<i>Potamogeton pectinatus</i> L.	I		Drains
Liliaceae			
<i>Astelia nervosa</i> Banks et Sol.	I	Forest	
<i>Collospermum hastatum</i> (Col.) Skottsberg	I	Forest	
Smilacaceae			
<i>Rhipogonum scandens</i> Forst.	I	Forest	
Lemnaceae			
<i>Lemna minor</i> Linn.	I		Drains
Typhaceae			
<i>Typha angustifolia</i> Linn.	I		X
Agavaceae			
<i>Phormium tenax</i> Forst.	I		X
<i>Cordyline australis</i> Hook. f.	I	X	X
Pandanaceae			
<i>Freycinetia banksii</i> A. Cunn.	I	Forest	
Orchidaceae			
<i>Dendrobium cunninghamii</i> Lindl.	I	Forest	
Juncaceae			
<i>Microtis porrifolia</i> R. Br.	I	X	
<i>Juncus bufonius</i> Linn.	N	X	X
<i>J. macer</i> S. F. Gray	N		X
<i>J. lampocarpus</i> Ehrh.	N		X
<i>J. effusus</i> Hook. f.	I		X
<i>J. polyanthemus</i> Buchen.	I		X
<i>J. vaginatus</i> R. Br.	I		X
<i>J. luxurians</i> Col.	I		X
Cyperaceae			
<i>Cyperus eragrostis</i> Lam.	N		X
<i>Gahnia xanthocarpa</i> Hook. f.	I	Forest	
<i>Mariscus ustulatus</i> (A. Rich.) C. B. Clarke.	I	X	X
<i>Uncinia uncinata</i> (L. f.) Kukenth.	I	Forest	
<i>Scirpus prolifer</i> Rottb.	I		X

Families and Species.	Indigenous (I) or Naturalized (N)	Main Habitat.	
		River Bank.	Semi- Swamp.
<i>Scirpus cernuus</i> Vahl.	I		X
<i>Carex virgata</i> Sol.	I		X
<i>Carex secta</i> Boott.	I		X
<i>Carex ternaria</i> Sol.	I		X
<i>Carex testacea</i> Sol.	I		X
<i>Carex pseudo-cyperus</i> Linn.	I		X
<i>Eleocharis acuta</i> R. Br.	I		X
Gramineae			
<i>Agropyron repens</i> (L.) Beauv.	N	X	
<i>Agrostis alba</i> L. pp.	N		X
<i>Agrostis tenuis</i> Sibth.	N		X
<i>Aira caryophyllea</i> L.	N	X	
<i>Aira praecox</i> L.	N	X	
<i>Alopecurus pratensis</i> L.	N		X
<i>Alopecurus geniculatus</i> L.	N		X
<i>Anthoxanthum odoratum</i> L.	N	X	
<i>Arundo kakaio</i> Steud.	I		X
<i>Avena fatua</i> L.	N	X	
<i>Bromus gussonii</i> Parl.	N	X	
<i>Bromus mollis</i> L.	N	X	
<i>Bromus catharticus</i> Vahl.	N	X	
<i>Briza media</i> L.	N	X	
<i>Briza minor</i> L.	N	X	
<i>Cynodon dactylon</i> (L.) Pers.	N	X	
<i>Cynosurus cristatus</i> L.	N	X	
<i>Dactylis glomerata</i> L.	N	X	
<i>Deyeuxia filiformis</i> (Forst. f.) Hook.	I	X	
<i>Echinochloa crusgalli</i> (L.) Beauv.	N	X	
<i>Festuca arundinacea</i> Schreb.	N	X	X
<i>Festuca elatior</i> L.	N	X	
<i>Glyceria maxima</i> (Hartr.) Holmb.	N		X
<i>Glyceria fluitans</i> L.	N		X
<i>Holcus lanatus</i> L.	N	X	
<i>Hordeum murinum</i> L.	N	X	
<i>Lagurus ovatus</i> L.	N	X	
<i>Lolium multiflorum</i> Lam.	N	X	
<i>Lolium perenne</i> L.	N	X	
<i>Microlaena avenacea</i> (Raoul) Hook. f.	I	Forest	
<i>Poa annua</i> L.	N	X	X
<i>Poa palustris</i> L.	N		X
<i>Poa pratensis</i> L.	N	X	
<i>Poa trivialis</i> L.	N		X
<i>Phalaris arundinacea</i> L.	N		X
<i>Phleum pratense</i> L.	N	X	
<i>Vulpia dertonensis</i> (All.) Volk.	N	X	
<i>Vulpia myuros</i> (L.) Gmel.	N	X	
Filices			
<i>Asplenium lucidum</i> (Forst. f.)	I	Forest	
<i>Asplenium bulbiferum</i> (Forst. f.)	I	Forest	
<i>Asplenium flaccidum</i> (Forst. f.)	I	Forest	
<i>Asplenium adiantoides</i> (L.) C. Christen.	I	Forest	
<i>Blechnum procerum</i> (Forst. f.) Labill.	I	Forest	X
<i>Cyathea medullaris</i> Schwartz.	I	Forest	
<i>Dicksonia squarrosa</i> (Forst. f.) Schwartz.	I	Forest	
<i>Dryopteris pennigera</i> (Forst. f.) Christen.	I	Forest	
<i>Hypolepis tenuifolia</i> (Bernh)	I		X
<i>Polypodium pustulatum</i> Forst. f.	I	Forest	
<i>Polypodium diversifolium</i> Willd.	I	Forest	
<i>Pteridium aquilinum</i> var. <i>esculentum</i> Hook. f.	I	X	
<i>Pyrrhosia serpens</i> (Forst.) Ching.	I	X	
Salviniaaceae			
<i>Azolla rubra</i> R. Br.	I		Drains.
Podocarpaceae			
<i>Podocarpus dacrydioides</i> A. Rich.	I	Forest	

VITAMIN CONTENT OF NEW ZEALAND MEATS: I. METHODS OF ASSAY FOR THE B GROUP VITAMINS

By W. A. MCGILLIVRAY, Biochemistry Department, Massey Agricultural College, Palmerston North.

Summary

The application of various methods of assay to the estimation of the major B group vitamins in animal tissues is described. Microbiological and chemical assay results have been found to agree well, variations generally ranging from 5 to 10 per cent. about the mean which is the order of variation normally encountered in methods of vitamin assay. In the case of niacin determinations in liver samples, however, occasional erratic variations of up to 30 per cent. have been encountered, the chemical methods giving the lower results. A chemical method is recommended for riboflavin and microbiological methods for the other members of the group. A note is also included on the chemical assay of thiamin and niacin.

INTRODUCTION

A WIDE range of chemical and microbiological methods is available for the assay of the major vitamins of the B group. With the sacrifice of possibly a small degree of accuracy, the chemical methods have largely been replaced by microbiological. The chief advantage of the latter, the most successful of which are those using lactic acid bacteria, depends on the fact that (1) no specialized equipment is required, (2) a large number of samples may conveniently be assayed at one time, and (3) they are in general less laborious and time consuming than the corresponding chemical methods.

After preliminary work using chemical methods, most of the assays carried out in this laboratory have been by these microbiological methods. There are, however, certain disadvantages and difficulties inherent in these methods and, while admitting their general superiority, it is considered that a chemical method based on a readily measureable natural physical property of the vitamin such as the fluorescence of riboflavin is likely to be at least as simple and satisfactory as a microbiological method. Further, where only a few assays are to be carried out, the advantage probably lies with the chemical methods.

For these reasons, particular attention has been paid to the chemical estimation of riboflavin and a satisfactory method is suggested.

SURVEY OF METHODS USED FOR VITAMIN ANALYSIS

Microbiological Methods.

A number of different microbiological methods have been suggested for the various B vitamins; the latest modifications for the more important of these are fully described in a recent handbook by Barton-Wright (1). The main objections to the microbiological methods as generally described, are (1) they require the preparation of a large number of stock solutions, many of which must be renewed regularly, and (2) there are difficulties in maintaining the bacteria in an active condition for long periods in chemical laboratories not equipped for this work and without the services of a bacteriologist. These difficulties have been overcome to a large extent

by the application of the freeze-drying technique to cultures of the various bacteria and to the media required (2)*.

In the carrying out of the assays a considerable saving of the time normally involved in plugging and handling test-tubes may be effected by the use of small bottles such as 20-ml. penicillin bottles. The normal rubber seal is removed and the bottles freed from any traces of penicillin by boiling with alkali. After running in the required amount of media and test solution, the bottles are protected by their loose-fitting aluminium caps only, and placed in trays for autoclaving. Protected in this way, the solutions remain sterile for considerably longer than the 72 hours required for carrying out most of the assays.

Microbiological methods based on yeast growth or yeast fermentation, which have been used extensively particularly in America for the assay of various members of the B group, have also been tested in this laboratory. Although the expected heavy growth was not obtained, yeast-growth methods such as that of Williams, McMahon and Eakin (3) for thiamin were found to be fairly satisfactory when applied to meat samples. Yeast-fermentation methods such as that of Schultz, Atkin and Frey (4) for thiamin require special equipment and are not readily applicable to more than a few assays. The correct strain of yeast for this method was not available and, as Bathurst (5) has reported, satisfactory gas evolution is not obtained with various local yeasts tested.

Somewhat improved results may, however, be obtained by growing a yeast on a thiamin-deficient media for two or three hours before preparing the inoculum, and by measuring the gas evolved during the second and third hours only. During the first hour the gas evolved is almost independent of the amount of thiamin present. A simple apparatus dispensing with the shaking device and the manometers was found to give a still greater increase in carbon dioxide per micro-gram of thiamin. A stream of carbon-dioxide-free air is passed through the fermentation vessels and the carbon dioxide carried with it adsorbed in dilute caustic soda and estimated at the end of the run using the method described by Piper (6). Reproducible results can be obtained provided the rate of passage of air is sufficient to give a good mixing and is uniform for each vessel. It was found necessary to add thiamin-free liver extract to the media to overcome non-thiamin stimulation.

Where, however, a strain of lactic bacteria may be used the yeasts appear to offer no particular advantages.

Chemical Methods.

All fluorimetric assays were carried out on the laboratory-built fluorimeter already described (7). The ultra-violet lamp in this apparatus was fitted with a Woods glass filter giving maximum transmission at $365\text{ m}\mu$ which is the optimum wave length for thiochrome fluorescence. Although the optimum for riboflavin is $436\text{ m}\mu$, it fluoresces strongly under the light transmitted by the Woods glass. The same reference solution, a dilute solution of sodium fluorescein, may be used for all fluorimetric analyses, since the sole object of this solution is to check variations in line voltage.

* The author is grateful to Mr. N. O. Bathurst, of the Plant Chemistry Laboratory, for drawing attention to this work and for demonstrating the technique.

For the thiochrome assays, there appears to be no advantage in substituting for the stable fluorescein the more usual quinine or thiochrome reference solutions with their inherent disadvantages of adsorption on the glass vessel and decomposition by the ultra-violet light respectively.

Riboflavin.

The property exhibited by solutions of riboflavin of giving an intense yellow-green fluorescence when exposed to ultra-violet or blue light has been used by a number of workers for its estimation. Widely different methods have been used by these workers to remove non-riboflavin fluorescing material and to determine the amount of such material still remaining, i.e., the blank. Because of these differences and because riboflavin lends itself so readily to chemical methods of assay on account of its natural fluorescence, various procedures for its estimation have been investigated and a simple accurate method obtained for determining riboflavin in meat samples. This method is a modification of that suggested by McLaren, Cover and Pearson (8) and differs from their method in the preparation of the extract and the pH at which the blank is read. The specificity of the method has also been investigated.

The general method for obtaining the blank is to destroy the riboflavin by exposure to sunlight or to reduce to the non-fluorescing form by the addition of a suitable reagent, the assumption being made that no non-riboflavin fluorescing material is destroyed, that the optical properties of the solution are not affected, and that none of the decomposition products are fluorescing.

Hodson and Norris (9) utilized sodium hydrosulphite to destroy the riboflavin and a preliminary hydrosulphite-stannous-chloride reduction to remove the bulk of the non-riboflavin fluorescing material. This method and modifications of it were found to be unsatisfactory when applied to animal tissues, as they gave results much lower than those obtained from other methods. Lately the method has been criticized by other workers (10). However, the failure may be partly due to the light source, since Kodicek (11) states that blue light rather than ultra-violet is essential.

Najjar (12) extracted the riboflavin into a non-aqueous phase after destroying interfering material by permanganate oxidation and obtained his blank by exposing this non-aqueous solution to light. A number of disadvantages in this promising method have been overcome recently by Slater and Murrell (13). Their modification was found to be most satisfactory when applied to animal tissues and, unlike other methods in which the riboflavin is destroyed by irradiation, it is possible to detect the destruction of other fluorescing materials. The method is, however, laborious when a large number of assays are to be made.

It was found that in the case of meat samples interfering material could be removed much more simply by precipitation at pH 5 and that a satisfactory blank obtained by adjusting to pH 12, when the fluorescence of riboflavin is destroyed.

Thiamin.

The thiochrome method for the estimation of thiamin has been found satisfactory for animal tissues although the blanks are rather higher than might be desired. The method used was that of Harris and Wang (14) adapted to the photoelectric fluorimeter. This method is somewhat more

lengthy than methods suggested by other workers (14), but it has been found that the extra steps such as the addition of methyl alcohol to protect the thiochrome, the preliminary washing of the extract with amyl alcohol (the use of which in place of butyl alcohol was suggested by Bathurst (5)) and the washing of the amyl alcohol solution of thiochrome with water did give better results with lower blanks.

It is recognized that the use of strong alkali and ferri-cyanide as an oxidizing agent is not entirely satisfactory, and in an effort to render the oxidation procedure easier to control, Holman (15) has suggested the use of mercuric oxide in the form of a dilute solution of caustic soda and mercuric chloride. Provided the temperature and time of heating are carefully controlled, this oxidizing agent gives good results, but with meat extracts at least, the method does not appear to offer any real advantages over the simpler Harris and Wang procedure.

The chemical method of Hirsch and Bergim (16) used widely for thiamin estimations, particularly in pharmaceuticals, was found to be unsuitable for meat samples.

Niacin.

Chemical methods for the estimation of niacin are generally based on the measurement of the yellow colour produced by the interaction of the vitamin with cyanogen bromide and an aromatic amine. Various amines have been tried by different workers; the most useful appear to be p-aminoaceto-phenone and aniline, and the majority of methods utilize one or other of these amines. The method of Melnick and Field (17) using aniline was found reasonably satisfactory for animal tissues. Since meat extracts are not normally highly coloured, the charcoal adsorption step may in general be omitted. Some workers, in particular Kodicek (18), have criticized the use of aniline rather than other amines. Kodicek shows that p-aminoacetophenone gives a much more intense colour than aniline. The colour, however, depends on the concentration of the amine and the lower sensitivity of the aniline may be overcome by using a 10 per cent. alcoholic solution in place of the two per cent. recommended by Melnick and Field. The use of this higher concentration is made possible by the higher alcoholic content of the extract, and no difficulty was experienced with the aniline coming out of solution. The aminoacetophenone method is sensitive to small variations in procedure and is not so simple or rapid as the aniline method.

Agreement between the microbiological and chemical methods for niacin was not so satisfactory as for thiamin and riboflavin. This applied especially in the case of liver assays, where the results from the chemical methods tended to vary somewhat erratically, due to difficulty in determining the true blank reading. In such cases the chemical methods always gave the lower results.

EXPERIMENTAL

Preparation of Extracts for Assay.

Whether for assay by the chemical or microbiological method, the preparation of samples was the same, being based on the methods recommended by Bathurst (5). In all cases each sample was minced and well mixed. A large sample (usually 25 to 50 g.) was agitated on a Waring Blendor with distilled water. The resulting suspension was made up to a definite volume (depending on the approximate vitamin content), the

volume occupied by the solid material in the sample being allowed for where necessary. Aliquots were then withdrawn and mixed with hydrochloric acid of sufficient strength to bring the total sample to the appropriate normality, viz. 0.25 N. in the case of thiamin and riboflavin, and N. for niacin. The tubes were plugged and after autoclaving at 15 lb pressure for 15 min., were stored in a cool place protected from light until assayed. Immediately prior to assay, thiamin samples were adjusted to pH 4.5, 0.2 g. of clarase added, and the samples incubated for 24 hours at 37°C. with a few drops of toluene.

In all cases absorption techniques with subsequent elution were avoided owing to the difficulties in completely recovering the vitamin (19). The Waring Blendor was used in preference to procedures such as grinding with sand (as recommended by several workers) to avoid the possibility of vitamin being absorbed on the sand (20).

Methods of Assay

With the exception of riboflavin all B vitamin assays described in the subsequent parts of this communication have been carried out using microbiological methods as described by Barton-Wright (1). In the case of riboflavin a chemical method has been used.

The extract was prepared, using the acid hydrolysis method already described. Enzyme digestion was not used, as it was found that autoclaving with the dilute acid gave as complete liberation of riboflavin as digestion with clarase or takadiastase and papain provided the sample was well mixed with the acid before autoclaving, preferably on a Waring Blendor. Further, enzyme digestion following autoclaving did not increase the amount of vitamin liberated. On the other hand, enzyme digestion, as well as introducing a correction for the riboflavin in the enzyme, increases in many cases the amount of interfering fluorescence.

After autoclaving, the sample was brought to a definite volume, adjusted to a pH of approximately 5 by using a sodium acetate—caustic soda buffer and shaken with 2 ml. of chloroform to remove fat which tends to render the solution turbid. At this pH, a fluorescent precipitate forms which is readily removed by centrifuging to leave a clear, almost colourless, solution. The volume of an aliquot of this solution is adjusted to give a suitable concentration of riboflavin for assay, the concentrations and the volumes depending on the particular fluorimeter in use.

5 ml. of the diluted extract is pipetted into the fluorimeter cell, mixed with 1 ml. of water and the fluorescence read (A). The cell is emptied, a second 5 ml. of extract added, mixed with 1 ml. of a standard riboflavin solution and the fluorescence again read (B). The cell is again emptied and a third 5 ml. of extract pipetted into it. The pH of this is adjusted to approximately 12 by the addition of 1 ml. of a phosphate-caustic soda buffer and the residual fluorescence measured (C).

Riboflavin in the original extract may then be calculated as follows:—

$$\text{Riboflavin in } \mu\text{g./ml.} = \frac{A - C}{B - A} \times \frac{\mu\text{g./ml. in standard solution}}{5}$$

To test the specificity of the method the fluorescence of riboflavin was determined at different pH values. The resulting pH—fluorescence curve indicates that riboflavin behaves as an amphoteric substance, only the un-ionized form being fluorescent. On the acid side, the experimental curve agrees well with the calculated logarithmic curve, $\text{pK} = 1.8$. On the

alkaline side, the same agreement is not obtained, due apparently to the destruction of riboflavin by the alkali, the shape of the curve depending on the time of contact with the alkali, pK approximately 9.8. That an ionization change is involved apart from the relatively slow destruction of the riboflavin by the alkali, is shown by the fact that, although the fluorescence is immediately destroyed on adjusting to pH 12, it may be regenerated to nearly its original intensity (depending on the time of contact with the alkali) on adjusting back to pH 5 – 7. No fluorescing by-products are formed since the fluorescence is completely destroyed at pH 12.

The fluorescence of liver and muscle samples was also measured over a range of alkaline pH values. Up to pH 12 the fluorescence – pH curves coincided exactly with that for pure riboflavin, but above this pH the non-riboflavin fluorescence was also reduced. If, however, any of this interfering fluorescence is affected below this pH, it must be affected in the same manner as riboflavin and must show the same departure from the calculated curve.

McLaren, Cover and Pearson (8) recommend the addition of one drop of saturated caustic soda to the extract in the fluorimeter cell to give the required pH for the "blank" determination. It is considered, however, that sufficiently precise control over the pH is not obtainable unless a definite quantity of a buffer is added, since above pH 12 the non-riboflavin fluorescence is also reduced, and below 12 the fluorescence of riboflavin is not completely quenched. A further advantage of the recommended procedure is that in a series of determinations all the blanks may be left to the last and there is no danger of traces of alkali in the fluorimeter cell affecting the pH of subsequent riboflavin estimations.

Using an internal standard method, the actual pH at which the fluorescence is read is unimportant. A pH of approximately 5 was chosen since at this pH the flocculent precipitate containing most of the interfering material is readily removed and the difficulty of frothing encountered with some extracts at pH 7 is not encountered. The fluorescence of riboflavin is almost unchanged between pH 5 and 7.

Although destruction of the riboflavin by light would possibly be a simpler method of determining the blank reading, it is not applicable to aqueous extracts since fluorescing decomposition products are formed. These products depend on the pH, being apparently lumiflavin in alkaline solution (21) and lumichrome in neutral or acid solution (22). Unless the fluorescence of these compounds is allowed for or eliminated with filters, erroneous results would be obtained for riboflavin in an extract.

TABLE I. RECOVERY OF ADDED RIBOFLAVIN FROM LIVER AND MUSCLE SAMPLES

Material.	Riboflavin Content. μg./g.	Riboflavin Added. μg./g.	Riboflavin Found. μg./g.	Recovery. Per cent.
Muscle 1	3.52	3.00	6.38	96
2	2.00	2.00	4.10	105
3	4.55	5.00	9.70	103
Liver 1	20.4	10.0	30.1	97
2	39.2	10.0	49.1	99
3	42.8	15.0	58.4	104

TABLE II. COMPARISON OF FLUORIMETRIC AND MICROBIOLOGICAL ASSAYS
ON LIVER AND MUSCLE SAMPLES

Material.	Fluorimetric. $\mu\text{g./g.}$	Microbiological. $\mu\text{g./g.*}$	Ratio Microbio- logical/Fluorimetric as Per cent.
Muscle 1	3.52	3.30	94
2	2.00	2.24	106
3	4.55	4.35	96
Liver 1	20.4	23.9	117
2	39.2	43.5	111
3	42.8	44.6	104

* Mean of 4 assays at 4 levels.

This simple fluorimetric method for estimating riboflavin gave good recoveries of added vitamin and results in good agreement with those obtained using the microbiological method as shown in Tables I and II. Individual assays were reproducible to within five per cent.

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VITAMIN CONTENT OF NEW ZEALAND MEATS

II. LAMB AND MUTTON

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Summary

Thiamin, riboflavin and niacin have been estimated in selected organs and muscles and Vitamin A in the livers from a group of fat lambs and from one mature ewe fed on pasture. Comparisons have been made between these animals and a group of animals fed on hay and concentrates. Significant differences have been found in the riboflavin content of livers and muscles and correlations are shown to exist between the amount of the B vitamins assayed in different muscles. A method is described for obtaining an indication of the average vitamin content of the different muscles from a carcass by the assay of niacin in the neck muscles. The vitamin content of the various tissues is shown to be of the same order as has been reported overseas.

INTRODUCTION

THE vitamin content of meat has been studied extensively particularly in America but little work has been carried out on New Zealand meats. Most of the overseas workers have been interested in the vitamin content of average commercial cuts as supplied to the consumer, rather than in the amounts present in the tissues at slaughter and the relation of this to the past history of the animal. The present paper gives results for the thiamin, riboflavin and niacin content of tissues taken from 25 lambs and one sheep raised on the Massey College farms during the seasons 1946 and 1947 for other projects under investigation at the College. One group of lambs and the sheep were raised under normal conditions. The other group of lambs had been raised under conditions of indoor feeding not normal in New Zealand, viz. with hay and concentrates, and were included to give an indication of the effect of such widely different treatments on the vitamin content of the tissues. As well as the B vitamins mentioned above, Vitamin A has been estimated in all livers and the pantothenic acid and biotin content of a few tissues determined.

With the exception of riboflavin, microbiological methods were used for all the B group assays. The micro-organisms, methods of assay and media used were those recommended by Barton-Wright (1). These microbiological methods lend themselves readily to the assay of large numbers of samples such as were handled in this investigation and once their technique is mastered are rapid and relatively simple to carry out. Riboflavin was estimated using the chemical method described in Part 1 of this paper.

Vitamin A was estimated using both activated Glycerol dichlorhydrin (GDH) (2) and the Carr-Price reagent. Excellent agreement was found between the two reagents as has also been shown by Sobel and Werbin (3). The extraction procedure was that described by Davies (4) and an internal standard was introduced into the estimation as first suggested by Oser, Melnick and Pader (5). With both reagents, the colour was measured using a photoelectric colorimeter which, as shown by Dann and Evelyn (6), greatly increases the accuracy of the Carr-Price method. Although the GDH reagent is easier to handle and gives a more stable

colour, with the introduction of the internal standard and a uniform procedure throughout, the Carr-Price reagent was found to give highly satisfactory and reproducible results.

EXPERIMENTAL

Description of the Animals

The group of lambs raised under normal conditions consisted of 12 Romney-Southdown lambs, eight ewes and four wethers, killed at as near to constant weight as possible. The mean hot carcass weight was 33.7 lb. (S.D. 0.9 lb.) and the average age 107 days (S.D. 7 days). The second group consisted of 12 Romney lambs, seven ewes and five wethers, reared indoors from birth until 21 days before slaughter when they were turned out to normal pasture. During the indoor period after weaning, the lambs were given a mixed feed consisting of: Lucerne Hay, 11 parts; Bran, 9 parts; Linseed Meal, 13 parts; Crushed Oats, 18 parts; and Peas, 13 parts. The lambs did not thrive well under the conditions of the experiment, only a few gaining weight regularly, and as most received a further set-back on being put on to pasture, they were in a poor condition when slaughtered. This change from indoor to outdoor feeding was part of another experiment outside the author's control. The mean hot carcass weight was 22.5 lb. (S.D. 3.3 lb.) and the average age 113 days (S.D. 4 days). The sheep was a four-year-old ewe normally reared on pasture—hot carcass weight, 60 lb.

In view of the results obtained from the indoor-fed lambs, one older lamb which had been fed indoors from birth until slaughter was assayed. This lamb, a wether, had gained weight consistently and was one of the best out of over 50 lambs in the indoor feeding experiment. When slaughtered, it was in good condition—hot carcass weight, 35.5 lb., age, 165 days.

Sampling

Organs required for assay were removed immediately after slaughter. As it was not possible to obtain all muscle samples at once, a standard procedure was adopted of taking all such samples after the carcass had hung for 48 hours in the cooler at a temperature of about 35° F.

All visible fat was removed from the tissues which were prepared for assay as rapidly as possible, using the methods already described. Individual muscles, as far as possible representative of the carcass, but which were readily accessible without undue mutilation of the carcass, were chosen for assay rather than for commercial cuts of meat.

RESULTS

The results for the various tissues assayed are set out in Tables I to V.

DISCUSSION

Normal Outdoor-Fed Animals

The animals of this group are of more interest since they are representative of normal New Zealand lamb and mutton. The tables show that although there is a fairly large variation between animals raised under apparently identical conditions and between different muscles from the same carcass, the average values are of the same order as those reported overseas. The values for the mature ewe are slightly lower than the

average for the lambs. Sufficient data are available from Tables I and III to enable correlations between the various vitamins to be calculated and these correlations are set out in Table VI.

The lack of correlation between the vitamin content of hearts and other muscles is probably explained by the small variations found in the former which were in many cases only of the same order as the experimental error. As might be expected, a significant (and in some cases highly significant) correlation exists between the amounts of the three vitamins in the muscles, whether different muscles from the same carcass or corresponding muscles from different animals are considered. The variations between muscles from the one carcass are considerably greater than those between corresponding muscles from different animals.

These variations were much greater than could be explained by the small variations found in the fat and moisture content of the muscles and, when calculated on a fat-free, moisture-free basis, variations in

TABLE I. VITAMIN CONTENT OF TISSUES (FRESH WEIGHT) FROM GROUP OF 12 LAMBS RAISED OUTDOORS ON PASTURE

	Thiamin.		Riboflavin.		Niacin.	
	$\mu\text{g./g.}$	S.D.	$\mu\text{g./g.}$	S.D.	$\mu\text{g./g.}$	S.D.
Liver	4.6	0.4	36.4	5.5	180	12.0
Heart	6.2	0.7	6.8	0.2	50.0	3.3
*Neck Muscle	2.3	0.3	2.7	0.3	53.2	5.8
*†Long. Dorsi	2.9	0.3	3.7	0.5	61.5	5.4
†Psoas Major	2.5	0.3	3.2	0.3	60.0	4.5
†Diaphragm	3.4	0.2	6.0	0.4	66.5	5.3

* Anterior neck muscles on either side of the vertebrae

† Taken at the junction of the last thoracii and the first lumbar.

‡ Assays on six animals only.

TABLE II. VITAMIN CONTENT OF TISSUES (FRESH WEIGHT) FROM GROUP OF 12 LAMBS RAISED INDOORS ON HAY AND CONCENTRATES

	Thiamin.		Riboflavin.		Niacin.	
	$\mu\text{g./g.}$	S.D.	$\mu\text{g./g.}$	S.D.	$\mu\text{g./g.}$	S.D.
Liver	4.5	0.6	49.0	5.5	171	13.6
Heart	6.7	0.8	6.9	0.3	49.0	9.8
Neck Muscle	2.4	0.3	3.9	0.5	57.5	7.4
*Long. Dorsi	3.0	—	4.1	—	62.0	—

* Assay on one animal only.

TABLE III. VITAMIN CONTENT IN $\mu\text{g./g.}$ FRESH WEIGHT OF TISSUES FROM MATURE EWE RAISED OUTDOORS ON PASTURE

	Thiamin.	Riboflavin.	Niacin.	Pantothenic Acid.	Biotin.
Liver	4.5	30.0	167	65	0.88
Heart	5.0	6.5	60.0	24	0.07
Kidney	4.6	20.5	85.0	—	—
Neck Muscle	1.3	2.9	44.5	3.8	0.02
*Other Muscles	2.0	3.1	49.0	4.1	0.023
S.D.	0.6	1.3	9.9	0.8	0.01

* Mean for eight representative muscles.

vitamin content remained of the same order. Wide variations have been reported in the amounts of connective tissue in different muscles (7) and it was thought that a negative correlation might exist between vitamin content and connective tissue. Using the enzyme digestion method of Mitchell and others (7) the connective tissue was determined in the muscle samples taken from the mature ewe. No significant correlation was found, but when calculated on a moisture, fat and connective tissue-free basis, the variations in vitamin content were somewhat smaller. A further possibility is that the vitamin content may vary with the amount of work a muscle is required to do. Hæmoglobin was therefore determined in the same muscles using a modification of the method for blood (8). Again, no significant correlation was found, but it is of interest to note that muscles such as the diaphragm with high hæmoglobin content are also rich in the B vitamins.

TABLE IV. VITAMIN CONTENT IN $\mu\text{g./g.}$ FRESH WEIGHT OF TISSUES FROM WETHER FED INDOORS ON HAY AND CONCENTRATES

	Thiamin.	Riboflavin.	Niacin.
Liver	5.5	46.0	198
Heart	5.9	—	63.5
Kidney	4.8	27.2	78.0
Spleen	2.2	5.8	61.0
Brain	2.6	5.0	51.5
Lung	1.6	4.5	59.5
Rumen Wall	1.2	3.0	47.0
Tongue	1.7	3.4	66.5
Neck Muscle	1.2	2.6	55.5
*Other Muscles	2.0	3.9	67.5
S.D.	0.4	0.9	11.0

* Mean for nine representative muscles.

TABLE V. VITAMIN A CONTENT OF LAMB LIVERS

	$\mu\text{g./g.}$	S.D.
12 outdoor lambs	115	8
12 indoor lambs	93	10
* 6 outdoor lambs	132	14

* A group of lambs killed after the main group at an average age of about five months.

TABLE VI. CORRELATION BETWEEN VITAMIN CONTENT OF VARIOUS TISSUES

	Correlation.
Considering the group of 12 lambs :—	
Vitamin A and B group content of livers	N.S.
Thiamin, riboflavin and niacin content of livers	N.S.
do. hearts	N.S.
do. neck muscles	H.S.
do. other muscles	S.
B group content of livers, hearts and muscles	N.S.
Considering individual animals :—	
Thiamin, riboflavin and niacin content of muscles	S.
H.S.	Significant at 1 per cent. level.
S.	Significant at 5 per cent. level.
N.S.	Not significant at 5 per cent. level.

The muscle samples assayed from these normal outdoor fed lambs are regarded as representative of the whole carcass. Since the correlation already mentioned exists between the amounts of the three B vitamins in the various muscles, it is possible to assess the approximate average vitamin content of all muscles from a carcass, by assays on one muscle only. Considering only the six lambs and the ewe where more than one muscle was assayed, the muscle with vitamin content most nearly equal to the average for all the muscles for each individual animal, was the Longissimus Dorsi which is 105 per cent of the mean with a standard deviation of 12 per cent. From the point of view of accessibility, however, a more suitable muscle to assay is the neck muscle which contains on the average 77 per cent of the mean for each animal with the same standard deviation. The calculation can be carried a step further and an indication of the amounts of all three vitamins present obtained by the assay of one vitamin only. Probably the easiest vitamin to estimate is niacin and from this thiamin and riboflavin figures may be obtained from the curves given in Fig. 1. These curves are drawn from the calculated equations:—

$$\text{Thiamin} = 0.55 + 0.0325 \text{ Niacin}$$

and Riboflavin = $0.23 + 0.047$ Niacin all expressed in $\mu\text{g./g.}$ fresh weight.

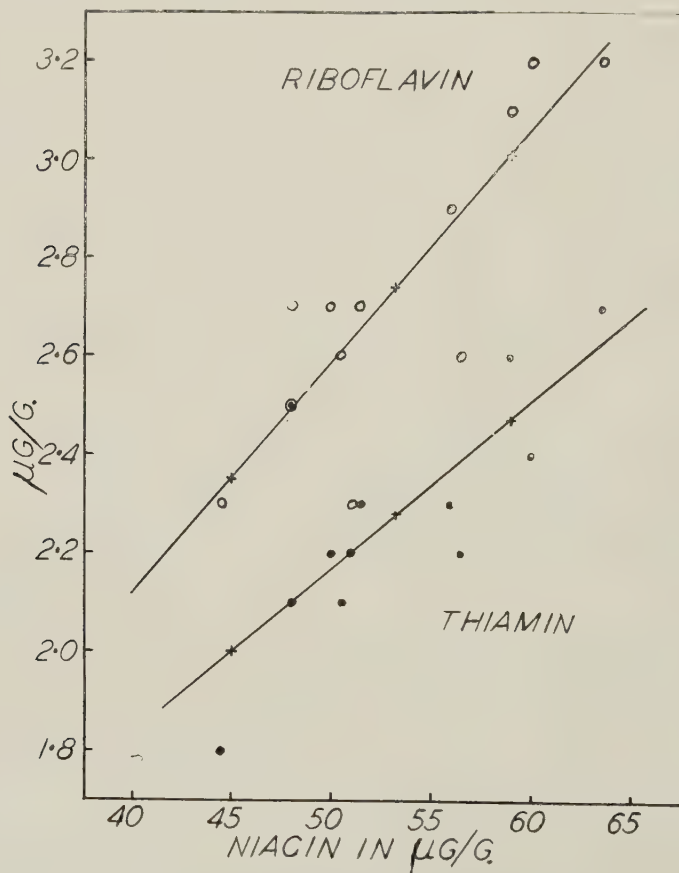


FIG. 1.—Correlation between thiamin, riboflavin and niacin content of muscle samples.

It is probable that the calculation could be extended to other members of the B group.

Indoor-Fed Animals

The group of indoor-fed lambs was much less uniform than the outdoor-fed animals and a greater variation in vitamin content was shown in most cases. No significant correlations were found between vitamin content of the different tissues except in the case of the muscle samples from the single wether (Table IV). Tables I and II show that there is little difference in the mean thiamin and niacin content of the tissues from the two groups. There is, however, a highly significant difference in the riboflavin content of the livers and the muscles from the two groups, indicating that the vitamin content of these tissues may be affected by the conditions under which the animals are raised. No conclusion can be drawn, however, because of the lack of correlation and the somewhat conflicting results from the lamb listed in Table IV. The high riboflavin content may be due to the indoor diet favouring increased synthesis by the microflora of the rumen. It is more probable that the differences would be explained by breed or by factors associated with the indoor feeding, such as lack of exercise resulting in different degrees of development of the various muscles, together with the poor condition of the lambs as compared with the outdoor-fed group. No significant sex differences were found in either group.

Considering the extremely different conditions under which the two groups of animals were raised and the differences in condition at the time of slaughter, the differences in vitamin content of the tissues are surprisingly small. Unless there is a large seasonal or age variation it is not likely that lambs of average quality raised under the reasonably similar conditions existing throughout New Zealand would differ markedly from the figures shown in Table I.

ACKNOWLEDGMENTS

The author desires to extend his thanks to Dr. C. R. Barnicoat who suggested the work and who gave much helpful advice throughout the investigation; to Messrs. J. H. Tetley, A. L. Rae, R. A. Barton and W. M. Webster for material and assistance in identification of muscles.

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NOTE ON BORON DEFICIENCY IN WHAREKOHE SILT LOAM

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IN the course of a trace element survey of New Zealand using plant indicators, a very striking growth response was obtained when borax was added to Wharekohe silt loam, a podzol derived from Cretaceous claystone collected from a virgin site under *Leptospermum* scrub at Purua, Whangarei County, North Auckland.

Wharekohe silt loam has a dark-gray, almost structureless, acid topsoil (pH 4.7); a low base exchange capacity (8.7 milligram equivalents per cent.); low total exchangeable base status (2.3 m.e. per cent.), giving a base saturation of 26 per cent.

For the experiment the soil was thoroughly mixed and sorted by hand for stones, roots, etc., but was not screened or dried as such treatment destroys the weak crumb structure of this soil. At the time of mixing the soil contained 15 per cent. moisture.

The experiment was conducted in glazed burnt clay pots 9 in. in diameter and 10 in. in depth, weighing about 30 lb. each when empty. A quantity of washed and waxed half-inch screened river gravel was placed in the bottom of each pot to facilitate drainage and bring the weight to exactly 35 lb. 22 lb. of moist soil was weighed out for each pot and, with the exception of soil required for the control pots, all soil was given a basal Ca + K + P + N treatment. Ca was added as CaCO_3 sufficient to bring the base saturation to 75 per cent., and was mixed into the soil 14 days ahead of all other treatments; K was added as K_2SO_4 equivalent to 2½ cwt. per acre; P was added as Na_2HPO_4 equivalent to phosphate in 5 cwt. super phosphate per acre; and N was added as NH_4NO_3 equivalent to 1½ cwt. per acre. The necessary quantities of each salt were made up for each pot in 100 cc. distilled water and this was worked into the soil before potting. A further 110 cc. distilled water was required to bring the soil to an optimum working condition and those treatments requiring trace elements received them in solution at this stage. All chemicals used were grade A.R.

Great care was taken to secure even filling and compacting in the case of every pot. When filled, the pots were kept inside for three days before being sown down to mustard (*Brassica alba*). The method of sowing ensured that there were 13 patches, each with 4 equal-sized seeds sown at a constant depth in each pot. After sowing, 31st March, 1948, the weight of each pot was made up to 59 lb. with distilled water and they were transferred outside.

A record was kept of germination, emergence and general appearance of seedlings. Twenty-six days after sowing, plants were thinned to 30 per pot and a visual rating was made at intervals until harvesting, when plants were removed, dried and weighed. All pots were weighed at intervals, and those which were underweight received additional water. Rainfall and temperature records were maintained during the experiment, and all pots were turned daily through 180°. The crop was harvested on 10th May, 1948, 41 days after sowing, and measurements taken for height and dry weight of plants.

Seven trace elements (Mo, B, Cu, Zn, Mn, Mg and Fe) were tried in amounts ranging from 2 lb. to 100 lb. per acre. and the experiment was conducted in quadruplicate.

The full results of this, and related, experiments will be reported subsequently. This note is intended to record that a very striking response was obtained with boron added as borax at 20 lb. per acre. In all treatments there was very close agreement between replicates at all stages of growth. In the control (untreated) pots, plants made very poor growth, and a number of plants died. In all pots receiving basal N, P, K and Ca, the growth was at least 500 per cent. better than in the controls, but when borax at 20 lb. per acre was added in addition to the basal treatment, a further 200 per cent. increase in growth was obtained. No other trace element gave a response comparable to this. The results of the boron treatment are summarized in Table I and Figs. 1 and 2, with control and basic N, P, K and Ca data for comparison.

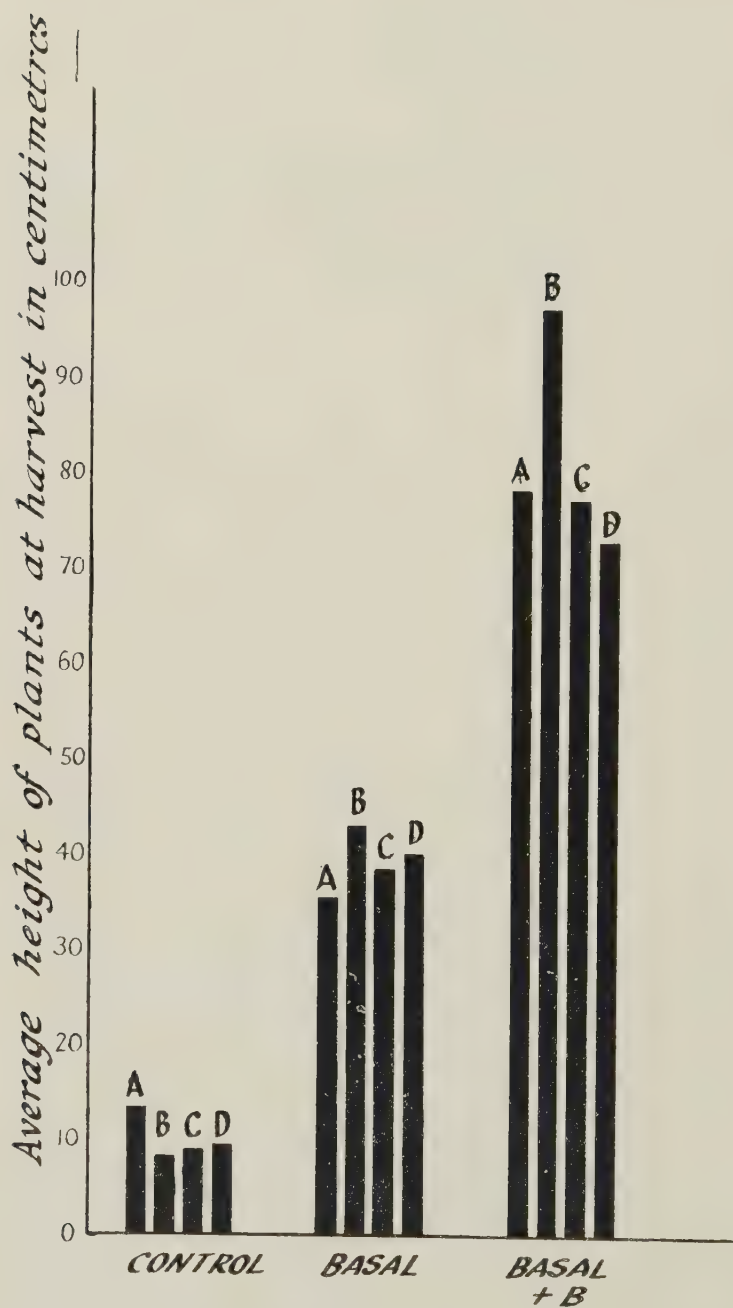


FIG. 1. Average height at harvest.

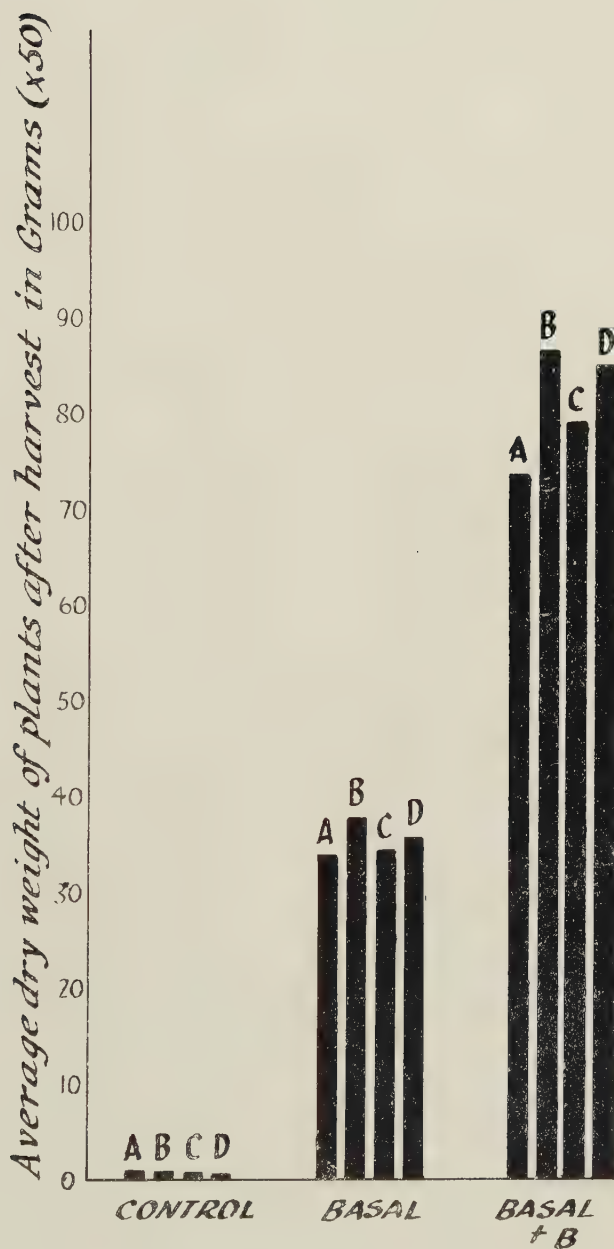


FIG. 2.—Average weight at harvest.

THE EFFECT OF PERIODS OF PRE-STORAGE DELAY ON THE GROUND-COLOUR AND COOL-STORAGE DISORDERS OF GRANNY SMITH APPLES

I. SUPERFICIAL SCALD

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(Received for publication, 13 April 1949)

Summary

Experiments with Granny Smith apples extending over three seasons have indicated that:—

(1) Pre-storage delay was not a practical means of controlling superficial scald in this variety.

(2) One of the factors limiting the practicability of this treatment was excessive yellowing induced by delay in storage.

(3) Immature fruit developed scald more readily than mature fruit.

(4) Packing in oiled wrappers gave an economic control of the disorder.

INTRODUCTION

DURING 1938, 1939 and 1940, conflicting results were obtained in New Zealand with delayed storage treatments and their effect on superficial scald of Granny Smith apples.

Results obtained by overseas workers were also conflicting. In Australia, Carne, Pittman and Elliot (1930), Broadfoot and Whittaker (1936), and a writer for the C.S.I.R. (1941), all recommended delayed storage as a control measure for scald. On the other hand Huelin and Tindale (1939) and Beare (1939) were not in favour of the practice. Whittaker (1943) reported limited uses for the treatment. In South Africa Isaac and Boyes (1939) found no constant differences between delaying and no-delaying treatments.

Early in 1942 it was decided to re-investigate this problem.

SYMPTOMS OF SCALD

Superficial scald affects the skin of the apple, and although the tissue beneath the skin is not visibly affected, the scalded areas may be slightly depressed. The colour of affected areas varies and may be grey-green to almost black. At other times the colour varies from light to dark brown according to the intensity of scalding.

Scald differs in its development. It may develop around lenticels in more or less circular areas, or it may appear as a diffuse marking in irregular patches which may be small in area or cover the whole apple. In severe cases of the latter type the affected areas have clearly defined margins.

Superficial scald does not always develop in cool-store, but may appear after an extended period of storage when apples are removed to a higher temperature. In store it is more likely to develop at high than low storage temperatures. Susceptible varieties will scald if held in cool storage for excessively long periods. Immature fruit is more liable to scald than mature fruit but the latter scalds in shorter time.

EXPERIMENTAL

The investigation was carried on for three years, all the fruit being supplied by Mr. T. Mitchell of Twyford, Hawke's Bay.

Two pickings, with approximately a month's interval between them, were made each year, the second picking coinciding with the normal picking time for the variety.

The fruit from each picking was divided into equal lots, one half being wrapped in plain sulphite wraps, the other half in oiled wraps.

Individual treatment samples consisted of two bushel cases in 1942 and one bushel case in 1943 and 1944.

Pre-Storage Conditions

Storage temperatures were 33-34°F. in 1942 when the fruit was held in a commercial storage chamber. In the last two years fruit was held in small experimental chambers at 32-33°F.

One sample in each type of wrap was stored immediately after each picking was received; thereafter, periods of pre-storage delay were from one to four weeks in 1942. These were increased to six weeks in 1943 and 1944, because the early results indicated that increased periods of delay might be more beneficial.

During 1942, prior to being placed in cool-store, the fruit was held in a constant temperature room at 20°C. and 90 per cent R.H. As these conditions proved to be too severe for the fruit and impracticable for commercial use, the fruit was, in the later years, held in a basement at air-temperatures, under conditions similar to those which would be used in practice. Daily temperatures ranged from a maximum of 73°F. in March to a minimum of 45°F. in June. Day to day temperatures fluctuated, but the general tendency was for them to drop as the winter approached.

Examination of Samples

Samples of a common maturity in similar wrappers were grouped and examined together.

No examination was made in 1942 until all the samples in a group were exhibiting some scald and one examination was made immediately the fruit was removed from store.

In 1943, to ascertain whether the fruit had any post-storage life, one examination was made on removal from store and a further one after the fruit had been held for 14 days at 20°C. and 90 per cent R.H.

Owing to the long period of storage the fruit had no post-storage life, so that in 1944 the experiment was repeated in modified form. Two examinations, the first in November, were undertaken for all treatments, irrespective of whether scald had appeared or not. November was chosen because the Granny Smith variety can be successfully cool-stored until then. The post storage life was also investigated at this stage, under similar conditions to those of 1943.

The second examination was carried out as in previous years, i.e. when all samples in a group had exhibited some scald, they were removed and examined immediately.

Recording of Scald

For recording purposes the disorder was divided into four categories, "trace," "slight," "moderate," and "severe," the last two being classed as commercially significant.

Colour Changes

In the first year it was observed that the ground-colour of the fruit changed from green to yellow with periods of pre-storage delay.

Measurements of the colour changes were made in 1943 and 1944 immediately the fruit was removed from storage, but not at later examinations.

Originally an initial measurement was made on 50 apples as soon as the fruit arrived for storage; later measurements were made on 25 apples.

Colours were matched against ten standard panels specially prepared to match the changes in ground-colour of Granny Smith apples. Values of colours ranged from a maximum of 12 (dark green) to a minimum of 3 (bright yellow).

RESULTS

Changes in ground-colour are presented in Table I.

With the exception of the 2nd pick in plain wraps in 1943, increased periods of delay under all treatments caused increased yellowing of the ground-colour. No explanation can be made for this one anomalous result.

Granny Smith is an apple which must be marketed green, so that there is a practical limitation to the period of delay which can be given. It was agreed by a panel of judges that any fruit rated below eight would be unacceptable on the market. It may be seen that permissible delay is limited to from three to four weeks for early pickings, and two or three weeks for late pickings, and not longer than two weeks if the fruit is intended for long term storage. There was a tendency for the oiled wraps to retard the yellowing of ground-colour.

Percentages of superficial scald are presented in Tables II to V.

These Tables show that delayed storage did influence the development of superficial scald, but not consistently. The most beneficial period for control of scald varied with the year, type of wrapper, fruit maturity, and duration of storage.

In some instances there were two or more periods of delay which were equally beneficial to fruit picked on the same day and wrapped in a particular type of wrapper. Thus in 1942, in three of the groups, scald was controlled equally well by immediate storage and four weeks delay.

As a general rule, fruit which was stored immediately scalded more readily than fruit with which there had been a period of delay before storage.

Throughout the experiment, oiled wraps prevented fruit from scalding for longer periods than did plain wraps. The first examination in 1944 showed that oiled wraps prevented the occurrence of significant scald in store until late November in both maturities and that periods of pre-storage delay were unwarranted. At this date there was no post-storage life left in the fruit.

Later pickings in both types of wrapper did not scald as badly as early pickings, but later pickings took slightly less time to scald than did earlier ones.

CONCLUSIONS

Under New Zealand conditions, delayed storage of Granny Smith is of no practical value in reducing the incidence of superficial scald. A large measure of control may be obtained by picking as late as possible and packing in oiled wraps.

TABLE I. AVERAGE INITIAL AND POST STORAGE COLOUR SCORES (1943 AND 1944) OF GRANNY SMITH APPLES

Period of Delay. (Weeks)	1943						1944						No. of Apples.
	—			—			1st Examination.			2nd Examination.			
	1st Pick Initial Colour. (50 apples) 11.88		2nd Pick Initial Colour. (50 apples) 11.88	1st Pick Initial Colour. (50 apples) 11.70		2nd Pick Initial Colour. (50 apples) 10.74	1st Pick Initial Colour. (50 apples) 11.70		2nd Pick Initial Colour. (50 apples) 10.74				
	Plain Wraps.	Oiled Wraps.	Plain Wraps.	Oiled Wraps.	Plain Wraps.	Oiled Wraps.	Plain Wraps.	Oiled Wraps.	Plain Wraps.	Oiled Wraps.			
Exam. Dates	18.10.43	6.1.44	23.11.43	24.1.44	15.11.44	20.11.44	22.11.44	22.11.44	9.1.45	10.1.45	15.2.45	16.2.45	25 in each sample
0	11.08	10.84	10.08	9.76	10.10	10.50	9.83	10.93	10.67	9.90	10.13	9.97	
1	10.68	10.20	9.64	9.28	10.07	10.60	9.47	10.20	10.33	16.17	9.83	9.80	
2	10.32	9.68	9.44	8.24	9.87	10.23	9.07	9.83	9.97	9.80	8.57	8.63	
3	9.92	9.52	10.20	7.12	9.43	10.07	7.40	8.47	8.00	9.50	6.87	7.30	
4	7.32	8.12	7.64	7.36	7.93	8.93	7.10	7.53	7.23	7.70	6.53	6.80	
5	7.04	7.04	7.12	7.12	6.37	6.83	6.53	7.00	6.50	6.37	5.23	6.33	
6	6.48	6.12	6.92	6.16	5.87	6.17	5.87	6.87	5.23	5.77	6.07	6.23	
Sig. Dif. P = .05	± 0.52	± 0.55	± 0.34	± 0.26	± 0.53	± 0.41	± 0.67	± 0.35	± 0.52	± 0.36	± 0.42	± 0.55	

TABLE II. 1942—PERIODS OF STORAGE AND PERCENTAGES OF SCALD ON REMOVAL FROM STORE

TABLE II. 1942—PERIODS OF STORAGE AND PERCENTAGES OF COMB AND SCALD ON REMOVAL FROM STORE																				
Period of delay. (weeks)	1st Pick, Plain Wraps.			2nd Pick, Plain Wraps.			1st Pick, Oiled Wraps.			2nd Pick, Oiled Wraps.										
	Removed from Store 12.10.42			Removed from Store 5.11.42			Removed from Store 7.12.42			Removed from Store 22.1.43										
	Storage Dates.	Storage Period. (Days)	No. of Apples.	Per cent. Commercially Significant	Total Percentage of Scald.	Storage Dates.	Storage Period. (Days)	No. of Apples.	Per cent. Commercially Significant	Total Percentage of Scald.	Storage Dates.	Storage Period. (Days)	No. of Apples.	Per cent. Commercially Significant	Total Percentage of Scald.					
0	26.3.42	200	263	26	72	1.5.42	188	263	3	40	26.3.42	256	263	3	31	1.5.42	263	260	1	39
1	2.4.42	193	263	69	94	8.5.42	181	261	15	64	2.4.42	249	263	23	59	8.5.42	256	259	—	24
2	9.4.42	186	262	69	97	15.5.42	174	263	21	65	9.4.42	242	260	12	51	15.5.42	249	262	—	34
3	16.4.42	179	254	67	96	22.5.42	167	262	5	39	16.4.42	235	260	2	37	22.5.42	242	256	—	9
4	23.4.42	172	259	33	80	29.5.42	166	262	2	31	23.4.42	228	261	3	40	29.5.42	235	260	—	12

TABLE III. 1943. PERIODS OF STORAGE AND PERCENTAGES OF SCALD

Period of Delay. (weeks)	1st Pick, 22.3.43						2nd Pick, 18.4.43					
	Storage Dates.	Storage age Per-iod. (days)	No. of Apples.	On removal from store * 18.10.43 ** 6.1.44		After additional 14 days at 20°C. and 90 per cent. R.H.	Storage Dates.	Storage age Per-iod. (days)	No. of Apples.	On removal from store * 23.11.43 ** 24.1.44		After additional 14 days at 20°C. and 90 per cent. R.H.
				Per cent. Commercially Significant Scald.	Total Per cent. of Scald.	Per cent. Commercially Significant Scald.				Per cent. Commercially Significant Scald.	Total Per cent. of Scald.	
PLAIN WRAPS.												
0	26.3.43	206	113	72	100	90	22.4.43	215	113	38	87	94
1	2.4.43	199	113	37	83	91	29.4.43	208	113	15	67	96
2	9.4.43	192	113	7	52	62	6.5.43	201	113	1	35	86
3	16.4.43	185	113	3	39	43	13.5.43	194	113	1	24	66
4	23.4.43	178	113	6	38	34	20.5.43	187	113	12	53	91
5	30.4.43	171	113	2	19	38	27.5.43	180	113	8	48	89
6	7.5.43	164	113	7	42	31	3.6.43	173	113	14	64	77
OILED WRAPS.												
0	26.3.43	286	125	61	96	96	22.4.43	277	125	20	66	99
1	2.4.43	279	125	38	79	94	29.4.43	270	125	26	72	97
2	9.4.43	272	125	41	69	91	6.5.43	263	125	18	48	96
3	16.4.43	265	125	20	50	91	13.5.43	256	125	13	34	98
4	23.4.43	258	125	9	40	84	20.5.43	249	125	8	24	100
5	30.4.43	251	125	6	36	70	27.5.43	242	125	8	32	97
6	7.5.43	244	125	3	23	56	3.6.43	235	125	3	30	97

* FRUIT IN PLAIN WRAPS.

** FRUIT IN OILED WRAPS.

TABLE IV. 1944. 1ST EXAMINATION. PERIODS OF STORAGE AND PERCENTAGES OF SCALD

Period of Delay. (weeks)	1st Pick. 28.3.44.				2nd Pick. 26.4.44.				After additional 14 days at 20°C. and 90 per cent. R.H.		
	Storage Dates.	Storage age period. (days)	No. of Apples.	On Removal from Store. * 15.11.44 ** 20.11.44		No. of Apples.	On Removal from Store. 22.11.44				
				Per cent. Commercially Significant Scald.	Total Per cent. Scald.		Per cent. Commercially Significant Scald.	Total Per cent. Scald.			
PLAIN WRAPS.											
0	31.3.44	234	122	80	94	100	137	100	2.5.44	203	125
1	7.4.44	227	121	22	63	100	137	100	9.5.44	196	123
2	14.4.44	220	124	2	40	98	136	90	16.5.44	189	113
3	21.4.44	213	125	—	9	98	138	90	23.5.44	182	125
4	28.4.44	206	124	1	3	95	133	67	30.5.44	175	125
5	5.5.44	199	125	1	7	86	138	86	6.6.44	168	121
6	12.5.44	192	123	2	10	85	129	85	13.6.44	161	122
OILED WRAPS.											
0	31.3.44	234	138	—	1	89	150	89	2.5.44	203	137
1	7.4.44	227	138	—	—	89	149	89	9.5.44	196	137
2	14.4.44	220	137	—	—	90	147	90	16.5.44	189	138
3	21.4.44	213	138	—	—	75	147	75	23.5.44	182	137
4	28.4.44	206	138	—	—	48	150	48	30.5.44	175	137
5	5.5.44	199	138	—	—	75	142	75	6.6.44	168	138
6	12.5.44	192	137	—	—	42	139	42	13.6.44	161	135

* FRUIT IN PLAIN WRAPS.

** FRUIT IN OILED WRAPS.

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